



FACULTY OF PSYCHOLOGY AND
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**Cognitive risk factors for depressive symptoms:
An experimental investigation of the interplay between
emotionally biased cognitive processes**

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Contents

Aims and outline	1
Chapter 1 Combined cognitive biases in depression	7
Chapter 2 Attending to remember	59
Chapter 3 Remembering to attend	101
Chapter 4 Cause and effect: Experimental modification of attentional bias	127
Chapter 5 Predictive magnitude of combined cognitive biases	173
General discussion	191
Data storage fact sheets	227
Nederlandstalige samenvatting	249

Aims and outline

Why do some people experience depressive episodes and other individuals never have to deal with this condition? Why do some individuals suffer from depressive episodes that seem to endure longer? These questions probing the mechanisms underlying depression have been puzzling investigators for decades and have given impetus to a myriad of research that identified biological, cognitive, and social factors that put people at risk to develop and/or maintain symptoms of depression (Dobson & Dozois, 2008). Numerous studies on cognitive risk factors have shown that emotional biases in cognitive processes such as attention, interpretation, and memory are closely linked to one's emotional state (Gotlib & Joormann, 2010; Mathews & MacLeod, 2005). At present, however, it remains unclear how these emotional biases in cognition operate together to affect emotional well-being: How do emotional biases in attention mechanisms regulate what is remembered? How does emotional long-term memory in turn guide attention? How does interpretation come into play in the attention – memory interaction? How do multiple cognitive biases in combination predict the course of depressive symptoms over extended periods of time?

The general objective of this doctoral research was to advance understanding of the mechanisms through which one cognitive bias influences another bias via systematic study of relations among depression-modulated biases in attention, interpretation, and memory.

Investigation of such multi-componential processes and their interactions requires a methodological approach with complementary research designs (see chapter 1). By triangulating empirical observations from cross-sectional (chapters 2 and 3), cognitive training (chapter 4), and longitudinal investigations (chapter 5), we aimed to map out parts of the potential interactions among processing biases in individuals with minimal as well as subclinical symptom levels of depression. The chapters included in this dissertation present a selection of theoretical and empirical efforts undertaken.

Molding a new line of investigation benefits from a thorough review of what has been learned from prior research to reveal what remains to be discovered about the relations among cognitive biases. In chapter 1, we first summarize prior research on the (causal) risk status of emotionally biased cognitive processes in depression and introduce the '*combined cognitive biases hypothesis*' (Hirsch, Clark, & Mathews, 2006) in the context of depression. Next, we present a selection of cognitive frameworks that could guide research on interactive cognitive biases and discuss past research testing relations between biased cognitive processes. We conclude this first chapter by outlining the major theoretical and clinical implications of potential advances in knowledge gained from this type of integrative research.

The empirical research presented in the following chapters can be organized into three core areas related to the combined cognitive biases hypothesis. There are cross-sectional studies investigating associations between cognitive biases (chapters 2 and 3), cognitive training studies testing hypothesized causal relations between these processes via experimental manipulation (chapter 4), and longitudinal studies examining the predictive value of multiple cognitive biases in combination (chapter 5).

The first series of experiments: how does emotional attention control and is controlled by long-term memory? In chapter 2, we

report three cross-sectional studies focusing on how individuals with varying depressive symptom levels attend to and remember emotional material. The first two studies examine how emotional attention during encoding regulates emotional biases in interpretation and explicit long-term memory. We hypothesized that explicit long-term memory for emotional material is directly related to biases in sustained attention and indirectly related to attentional selection via its relation with interpretation bias. In a third study, we aimed to further understanding of the role of attention bias during retrieval of emotional information. Based on basic cognitive research, we hypothesized that attentional mechanisms regulate emotional memory during controlled and not during automatic retrieval of emotional material.

Building on this work, in chapter 3, two experiments examine how emotional long-term memory representations guide attention. The first experiment tested whether attention is guided by emotional memory and if individual differences in depressive symptom levels modulate attentional guidance by positive versus negative associations in memory. The second experiment examines which attention operations are controlled by emotional memory as well as the temporal profile of memory-based attention bias. We hypothesized that emotional memory has the ability to guide attention toward congruent material, mainly affecting early attentional operations.

In chapter 4, we follow up on the cross-sectional research observations by a series of three experiments attempting to manipulate emotional biases in attention to investigate its assumed causal impact on affective task-switching ability and interpretation bias. We hypothesized that training attention allocation toward emotionally positive or negative material modulates the flexibility of switching between emotional and non-emotional features of non-trained stimuli and alter subsequent interpretation of emotional

material in a training-congruent manner. Based on observations from the first three experiments, we sought to gain a better understanding of the nature of attention and interpretation biases typically targeted by cognitive bias modification procedures. Here, we modeled relations between depression levels, attention bias, and interpretation bias while distinguishing between processing tendency and ability processes. We hypothesized that attention bias mediates the relation between depressive symptoms and interpretation for both tendency and ability processes.

The empirical studies presented in the previous chapters tested interactive cognitive biases in relation to depressive symptoms within a proximal timeframe, leaving unanswered how cognitive biases in combination impact the longitudinal course of depressive symptoms. In chapter 5, we investigate different integrative approaches that model the combined impact of multiple biases in the prediction of prospective changes in depressive symptoms over a follow-up period of one year. Specifically, we explore the predictive value of additive (i.e., negative cognitive biases have a cumulative effect) and weakest link (i.e., the dominant pathogenic process is important) approaches in interaction with perceived stress.

What is the increment in knowledge this PhD research provides to the literature on emotional biases in cognition? In the last chapter of this dissertation, the general discussion, we summarize the little parts of the complex interactions among cognitive biases that we have unlocked and discuss their implications for cognitive theory, research, and clinical practice. It will be clear that research integrating multiple cognitive biases is at an early stage and that the insights gained here raise more fascinating empirical questions. We conclude by outlining recommendations and directions for future study to deepen our understanding of cognitive risk factors in depression.

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Chapter I

Combined Cognitive Biases in Depression¹

Major depression is a highly prevalent and recurrent psychiatric illness with a severe personal and societal burden (Kessler & Wang, 2009). Despite efficacious psychological and pharmacological treatment strategies (National Collaborating Centre for Mental Health, 2010) there is ample room for improvement: relapse and recurrence rates of depression remain high after recovery and a considerable group of individuals does not respond to treatment (Boland & Keller, 2009). This indicates that current therapies do not sufficiently target the (causal) risk factors for this burdensome disorder. Efforts to identify the mechanisms involved in the onset and maintenance of depressive symptoms are particularly pressing to further understanding of depression and how best to prevent and treat this condition.

Intensive research has been successful in identifying cognitive risk factors for depression. Apart from a large body of research examining depressive cognitive content as a vulnerability factor (e.g.,

¹ Based on 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.

negative thoughts, dysfunctional attitudes), a promising line of investigation highlights the role of emotionally biased cognitive processes in the onset and maintenance of depression (Gotlib & Joormann, 2010; Mathews & MacLeod, 2005). Research efforts in this area have typically focused on processing abnormalities in attention, interpretation, and memory, which are considered to be instrumental in the understanding of the processes involved in cognitive biases. More recently, there is growing interest into cognitive and neural mechanisms underlying cognitive control impairments, which may operate across a variety of cognitive biases. Indeed, a substantial number of studies on emotional processing in depressed samples provide evidence that depression is characterized by negative biases in basic cognitive processes such as attention, interpretation, and memory. This research has been guided by comprehensive cognitive frameworks of depression (D. A. Clark, Beck, & Alford, 1999; Ingram, 1984; Williams, Watts, MacLeod, & Mathews, 1988, 1997) and have led to the development of specific cognitive science approaches to depression (Holmes, Lang, & Deerprouse, 2009; Joormann, Yoon, & Zetsche, 2007).

Cognitive Biases as Causal Risk Factors

What are the main findings on cognitive processing biases in depression? First, research on emotional biases in attention has shown that at-risk (e.g., subclinically or remitted depressed) and clinically depressed individuals show an attention bias favoring negative material and do not have a bias toward positive material typical for non-depressed individuals (Peckham, McHugh, & Otto, 2010). Depression-related biases in attention toward negative material are thought to be characterized by impaired withdrawal of attention from processing negative material rather than facilitated attention toward negative stimuli (De Raedt & Koster, 2010). Second, at the level of interpretation, subclinically and clinically depressed individuals tend draw more negative interpretations on ambiguous information. The current

research evidence suggests that ambiguity resolution is negatively biased during the effortful generation of interpretations and selection of a certain interpretation as most likely applicable to an ambiguous situation (Berna, Lang, Goodwin, & Holmes, 2011; Hindash & Amir, 2012; Sears, Suzie Bisson, & Nielsen, 2011; Wisco & Nolen-Hoeksema, 2010; Wisco, 2009). Third, research on emotional memory has reliably demonstrated that depression is marked by biases in explicit memory, with depressed individuals remembering generic and more negative events than specific and positive experiences compared with non-depressed individuals (Matt, Vazquez, & Campbell, 1992; Williams et al., 2007). A recent meta-analysis revealed that depressed individuals have also an implicit memory bias. Compared to non-depressed people who have an implicit recall bias, depressed people implicitly recall more negative self-relevant stimuli when encoding and retrieval match in terms of perceptual and conceptual processing demands (Gaddy & Ingram, 2014; Phillips, Hine, & Thorsteinsson, 2010). Finally, recent studies also point toward depression-related impairments in cognitive control. Depressed individuals have difficulties in inhibiting negative information (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; Goeleven, De Raedt, Baert, & Koster, 2006; Gotlib et al., 2004; Joormann, 2004), shifting, and updating emotional and non-emotional representations in working memory (De Lissnyder et al., 2012; Levens & Gotlib, 2010; Lo & Allen, 2011; Yoon, LeMoult, & Joormann, 2014).

Longitudinal research and cognitive bias modification studies (i.e., experimental manipulation of emotional processing biases) suggest that cognitive control deficits (Calkins, McMorran, Siegle, & Otto, 2014; Demeyer, De Lissnyder, Koster, & De Raedt, 2012; Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013; Siegle, Ghinassi, & Thase, 2007; Zetsche & Joormann, 2011), biases in attention (Baert, De Raedt, Schacht, & Koster, 2010; Browning, Holmes, Charles, Cowen, & Harmer, 2012; Wells & Beevers, 2010; Yang, Ding,

Dai, Peng, & Zhang, 2014), interpretation (Blackwell & Holmes, 2010; Holmes, Lang, & Shah, 2009; Lang, Blackwell, Harmer, Davison, & Holmes, 2012; Menne-Lothmann et al., 2014; Rude, Durham-Fowler, Baum, Rooney, & Maestas, 2010; Rude, Valdez, Odom, & Ebrahimi, 2003; Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002), and memory (Asarnow, Thompson, Joormann, & Gotlib, 2014; Bellew & Hill, 1991; Johnson, Joormann, & Gotlib, 2007; Raes, Williams, & Hermans, 2009; Reilly-Harrington, Alloy, Fresco, & Whitehouse, 1999; Rottenberg, Joormann, Brozovich, & Gotlib, 2005; Sumner, Griffith, & Mineka, 2010; Van Daele, Griffith, Van den Bergh, & Hermans, 2014) can predict and contribute to the onset and maintenance of depressive symptoms. Moreover, these emotionally biased cognitive processes are associated with emotional responses to stressors (Clasen, Wells, Ellis, & Beevers, 2013; Ellenbogen, Schwartzman, Stewart, & Walker, 2002; Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013) and have been observed in never-depressed at-risk (Dearing & Gotlib, 2009; Joormann, Talbot, & Gotlib, 2007; Kujawa et al., 2011; Taylor & Ingram, 1999) and in remitted depressed (Fritzsche et al., 2010; Gilboa & Gotlib, 1997; Hedlund & Rude, 1995; Joormann & Gotlib, 2007; Romero, Sanchez, & Vazquez, 2014) samples.

Although several recent studies did not report evidence for the role of cognitive biases in depression (Kruijt, Putman, & Van der Does, 2013; Onraedt & Koster, 2014; Wisco, Treat, & Hollingworth, 2012), the accumulated research data yields strong evidence for depression-related cognitive biases in different cognitive processes and indicates that these processing biases are not merely mood-dependent correlates of depression. Rather, cognitive biases may increase risk for depression. It has been argued that these cognitive biases are vulnerability mechanisms or causal risk factors through which depressive symptoms develop and are maintained.

The Interplay Among Cognitive Biases

A major limitation of previous research is that cognitive biases in depression have been mostly studied in isolation. While this approach has some advantage in improving our understanding of how a specific cognitive bias affects behavior, it is limited in that it does not inform on how multiple cognitive biases interact or how these processes are linked to higher-order factors (e.g., negative schema's, see below). Also, a focus on individual biases provides a limited understanding of the relative importance of how various biases in combination may influence the onset, maintenance, and/or relapse of depression. A comprehensive understanding of depression-linked cognitive biases can only be gained by investigating relations among emotional biases in multiple cognitive processes.

This review applies the *combined cognitive biases hypothesis* (Hirsch, Clark, & Mathews, 2006) to the study of depression. We attempt to frame how cognitive biases operate in concert and elaborate upon the main empirical questions arising from the combined cognitive biases hypothesis. We follow by discussing predictions from key theoretical frameworks that can inform upon the interplay among cognitive biases, guiding future research in this area. Then, we draw upon empirical studies that have directly examined links between multiple cognitive biases. We conclude with theoretical and clinical implications of the current findings and propose a number of ways in which this new area of research can be taken forward.

The Combined Cognitive Biases Hypothesis

Although many cognitive models of psychopathology assume interactions among cognitive biases, their take on this assumption has been relatively limited (see theoretical accounts section). It is only recently that specific ideas and hypotheses regarding the interplay between emotionally biased cognitive processes in emotional disorders have begun to emerge in clinical cognition research (Hertel, 2004). In

a paper focusing on bidirectional relations between interpretation bias and imagery, Hirsch et al. (2006) elaborated upon the notion of distorted cognitive processes working in concert and formulated the combined cognitive biases hypothesis (CCBH). It was argued that “*cognitive biases do not operate in isolation, but rather can influence each other and/or can interact so that the impact of each on another variable is influenced by the other. Via both these mechanisms we argue that combinations of biases have a greater impact on disorders than if individual cognitive processes acted in isolation*” (p. 224). Although framed within research on social anxiety disorder, the CCBH can be applied to *healthy* and *emotionally disordered* cognitive functioning.

Table 1. *Research questions originating from the combined cognitive biases hypothesis.*

Category	Description
Association	Questions probe associations among emotional biases in components and systems of cognitive control, attention, interpretation, and memory.
Causal	Questions concern the causal direction of observed associations between cognitive biases: have biases unidirectional and/or reciprocal relations?
Predictive magnitude	Questions involve how multiple biases in combination (e.g., via weakest link, additive, interactive effects) influence the depression course.

There is an upsurge of research on relations between cognitive biases related to depression (see empirical data section). However, this research is at the beginning stages and several open questions need future investigation. We have identified three broad categories of research questions originating from the CCBH, namely association, causal, and predictive magnitude questions. Table 1 summarizes the key features within each type of research questions.

Association Questions

A first category of questions concerns what we refer to as ‘association questions’. These questions address whether cognitive control impairments and emotional biases at the levels of attention, interpretation, and memory are related. Although several studies drawing from ‘association questions’ (e.g., “are negative attention biases associated with enhanced memory for similar information?”) have been published (see empirical data section) many potential linkages have not been systematically explored. For example, no published research reports data on the relation between emotional biases in attention and interpretation in depression, though influential cognitive models (e.g. Beck’s schema theory; see below) assume that there is a link. In addition, current research is highly underspecified with regard to the cognitive processes under study in that only broad relations between measures of the constructs of ‘attention’ and ‘memory’ were investigated, though these cognitive processes are not unitary entities (Chun, Golomb, & Turk-Browne, 2011). Attention involves multiple components or operations (e.g., selective orienting, sustained attention) and multiple systems comprise memory (e.g., working memory, explicit and implicit memory long-term memory). Interactions between emotionally biased cognitive processes may occur among different components and systems at different processing stages (i.e., encoding, (re)consolidation, and/or retrieval of emotional material). Hence, the complexity of the distinct components and systems of cognitive processes should be integrated into tests of the CCBH. Accordingly, findings from studies examining association questions can provide detailed insights about various functional relations among multiple biased cognitive processes.

Causal Questions

The direction of the hypothesized influence of one cognitive bias on another process are the focus of causal questions. Within this

category, there are two issues that deserve future empirical scrutiny. A first issue concerns the chain of effects. It has not been tested yet whether multiple cognitive biases operate in succession (i.e., unidirectional effects) with one bias influencing another process which in turn could affect a third process. For example, biases in attention may alter interpretation which may in turn regulate memory. Alternatively, cognitive biases may operate constantly and in parallel across multiple processing stages. For example, emotional biases in attention may not only regulate memory via their impact on encoding, but may also bias memory via its influence on retrieval of emotional information. A second issue within the category of causal questions is whether there are reciprocal relations between different biases. For example, emotional biases in attention (e.g., a critical remark of a loved one) may lead to negative interpretations of the attended material (e.g., “she/he does not love me anymore”), which may in turn guide attention to similar material (e.g., other signs of disapproval) to strengthen the initial interpretation (e.g., “he/she hates me”).

In investigating association and causal questions, it is important to consider whether the interplay among distorted cognitive processes has differential effects depending on the depression phase (i.e., at a non-depressed at-risk, subclinical, clinical, or remitted stages). As we discuss later, the strength of processing abnormalities may partially depend on depression severity levels and the number of past depressive episodes, suggesting that interactions between cognitive biases may not be static over time but change across stages and over the course of multiple depressive episodes. This warrants research scrutinizing association and causal questions in samples of at-risk and currently depressed individuals.

Predictive Magnitude Questions

While the first two types of questions concern relations among depression-linked cognitive biases within proximal timeframes,

predictive magnitude questions address the influences of single versus multiple cognitive biases in combination on the longitudinal course of depressive symptoms (i.e., a distal timeframe). At present, it remains unknown whether depressive symptoms are exacerbated or maintained by single or multiple cognitive biases, and which (combination of) biases yield the greatest potency in predicting the symptom course over time. Some cognitive biases (e.g., attention) could be a proxy risk factor via its influence on another process (e.g., memory) which in turn predicts the course of depressive symptoms. Some cognitive biases (e.g., interpretation) could mediate or moderate effects of one bias (e.g., attention) on changes in depressive symptoms. Alternatively, multiple cognitive biases could be overlapping risk factors individually predicting fluctuations in depression (Kraemer, Stice, Kazdin, Offord, & Kupfer, 2001). Of particular interest to predictive magnitude questions are research questions probing whether cognitive biases have additive (i.e., cognitive processes have a cumulative effect) effects on the course of depressive symptoms or whether the weakest link (i.e., the dominant pathogenic process is important) is the best marker of future depression, and if the predictive effect of such integrative models extends beyond effects of a single cognitive bias.

Addressing predictive magnitude questions is essential to improve insight into the multifactorial risk processes involved in depression. It seems plausible that multiple risk factors may increase the probability of developing a disorder whereas an individual factor may not. Applied to the topic under study here, individual biases have only small to moderate explanatory power and it is likely that multiple interactive cognitive biases explain a larger proportion of variance in longitudinal fluctuations in depressive symptom severity.

As argued in the context of each category of questions, we propose that instead of examining biases as independent, isolated factors, mutual influences among multiple cognitive biases need to be

taken into account to improve understanding of each individual cognitive bias and depression-linked distortions in cognitive functioning as a whole. Later in this article, we review current empirical research per category of CCBH questions. We first consider theoretical predictions on the CCBH in depression, as they can guide future empirical research in this area.

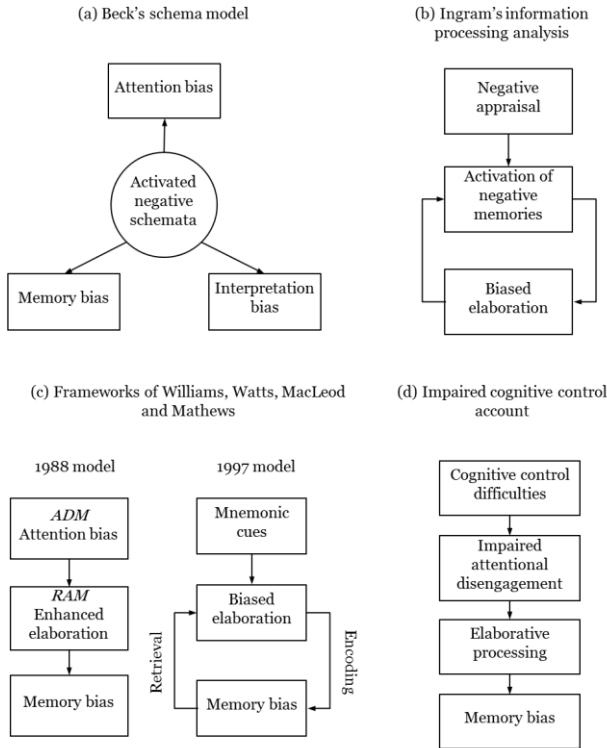


Figure 1. Schematic depiction of hypothesized relations among cognitive biases by cognitive frameworks of depression.

Cognitive Frameworks of Depression

Various cognitive frameworks of depression assert that biases in attention, interpretation, memory, and cognitive control play a crucial role in the onset, maintenance, and relapse of depressive symptoms. In this section, we briefly describe the most influential

cognitive models with their shared and unique predictions with respect to the different categories of CCBH questions. Figure 1 provides a schematic outline of the distinct models.

Beck's Schema Theory

One of the most influential cognitive accounts of depression is Beck's schema theory (Beck & Haigh, 2014; D. A. Clark et al., 1999). The theory asserts that depression-prone individuals hold negative schemas or dysfunctional memory representations about the self (i.e., on themes of personal loss, failure, or deprivation), that are developed through a complex interaction between genetic factors, selective attention, and memory with adverse life events. When schemas are activated by stressful life events (e.g., a relationship breakup, an oral exam), its content interacts with processing biases in attention, interpretation, and memory in a schema-relevant manner. An example: a student with a history of failing oral exams might be more attentive for social cues of disapproval during new exams (e.g., an examiner frowning his eyebrows). The student may interpret such cues in a negative manner (e.g., "I must have given a stupid answer") and recall negative memories about past failures (e.g., experiences associated with previous times failing an exam). These cognitive biases are assumed to occur interactively and concurrently during automatic and strategic processing (D. A. Clark et al., 1999). Although this prediction is relevant to association questions, the theory does not provide a detailed account of testable hypotheses on causal relations among specific cognitive biases. Regarding fluctuations in the relations among biases across different depression phases, the theory asserts that the magnitude of negative biases in attention, interpretation, and memory are a linear function of depressive symptom severity (D. A. Clark et al., 1999). It is hypothesized that a cognitive shift occurs from a positivity bias in healthy people to facilitated processing of negative information in clinically depressed people.

Whereas Beck's cognitive model predicts emotional biases across all cognitive processes (i.e., attention, interpretation, memory biases) at both automatic and strategic processing levels, other cognitive theorists (Ingram, 1984; Williams et al., 1988, 1997) have proposed a more specific set of predictions regarding relations among depression-linked cognitive biases.

Enhanced Elaboration Accounts

Ingram's information processing analysis

Ingram (1984) attributes a central role to biased elaboration and memory in maintaining depression (association question). Drawing on Bower's theory (Bower, 1981) on mood and memory, the model assumes that when depressive memory networks are activated by appraisals (interpretations) of life events, individuals elaborate extensively upon information that is congruent with the triggered negative cognitions. In keeping with the previous example, a student may appraise certain cues (e.g., frowned eyebrows, crossed arms) as signs of failure (e.g., "my answer is not correct") which may activate corresponding memory networks resulting in a thorough evaluation of the attributes and implications of the situation (e.g., "I did not understand the theory very well, I will not pass the exam, I am stupid"). It is hypothesized that this selective processing style activates connected memory networks via associative linkages, which may contain negative cognitions that are related to past feelings of sadness or depression (e.g., "I screwed up my romantic relationships, I am a loser"). Activation of such connected networks maintains biased elaboration on negative material (causal question). As a result of this process of recycling of negative cognitions through various memory networks, the elaborated material is encoded more deeply into the memory networks increasing the likelihood that this negative memory content becomes activated in the future. The elaboration – memory

interaction heightens the vulnerability for depression and predicts future depressive episodes (predictive magnitude question).

Williams et al.'s cognitive framework

According to Williams et al. (1988) depression is characterized by negative biases in elaboration and not in priming processes of attention and memory (association question). While priming refers to automatic processes involved in strengthening representations to make them more accessible, elaboration refers to strategic processes that form or strengthen relations between activated representations (Graf & Mandler, 1984). Two mechanisms are proposed to underlie these negative biases: the affective decision mechanism (ADM) and the resource allocation mechanism (RAM). When incoming information is evaluated as negative (e.g., frowned eyebrows), as assessed by the ADM, more attention resources are allocated to negative material (e.g., the examiner rolling his eyes, crossed arms) resulting in enhanced elaboration (RAM). For example, the student may think "I must have given a wrong answer, I am not capable of passing the course". Such depression-related elaborations are encoded into memory, enhancing later recall of this material (causal question). Based on the available empirical data, Williams et al. (1997) concluded that depression is not featured by mood-congruent biases in attention (association question), in that way contradicting predictions by Beck's model. According to the reformulated model, depressed individuals engage in strategic or biased elaboration upon negative material during memory retrieval. This enhanced elaboration results in improved memory for negative material and the products of the elaboration process serve as mnemonic cues at later points in time (causal question).

Impaired Cognitive Control Accounts

Executive control has been proposed as an overarching mechanism operating across cognitive biases at various processing

stages (Hertel, 1997; Joormann, Yoon, et al., 2007; Joormann, 2010). The impaired cognitive control account by Joormann and colleagues specifies a causal chain linking deficits in cognitive control to cognitive biases (causal question). The model hypothesizes that depressed individuals have difficulties in limiting access of irrelevant negative information into working memory (WM) and removing negative content from WM that is no longer relevant. This means that negative cognitions remain active in WM (e.g., “I failed last time, why would I succeed now”) and may interfere with the current performance on a task (e.g., when one is preparing for the next exam). These deficits in cognitive control are assumed to underlie difficulties in disengaging attention from negative information resulting in enhanced elaboration on this material. As a result, negative elaborations or interpretations are stored into long-term memory which sets the stage for memory bias. The causal relations among cognitive biases put forward by the impaired cognitive control account are different from assumptions by Beck’s cognitive model and enhanced elaboration accounts. Whereas theories by Beck and Ingram predict that cognitive biases are produced by cognitive schemas as higher-order factors, Joormann et al. predict a chain of biases driven by cognitive control processes.

Summary

Cognitive frameworks stipulate that emotionally biased cognitive processes are central mechanisms in the onset, maintenance, and relapse/recurrence of depressive symptoms, however, the theories differ in the extent to which they integrate multiple biased cognitive processes, elaborate on the interplay among these factors, and make specific predictions regarding pathways through which cognitive biases in combination impact the course of depressive symptoms over time. Hence, the CCBH can be applied to examine the competing hypotheses arising from these different theoretical frameworks. Yet, despite meaningful shared and differential predictions, the existing models are

often ambiguous and underspecified as far as the dynamic interplay among cognitive biases is concerned (recall that attention and memory are not unitary entities). The sections below provide an overview of current research reporting data relevant to the CCBH.

Empirical Research on Combined Cognitive Biases

There is increasing research studies investigating relations among emotional biases attention, interpretation, and memory in various depressed samples. Below we review the research findings per CCBH research question.

Association Questions

Empirical research relevant to association questions has exclusively focused on emotional biases in attention and explicit memory. A seminal investigation (Gotlib et al., 2004) explored correlations between these biases in a sample of clinically depressed patients and never-disordered control individuals. In this study, participants started with an encoding task prompting them to evaluate the self-relevance of positive, negative, and neutral words, which was followed by an incidental free recall task to test memory for the encoded items. Next, to measure attention biases toward sad, angry, or happy material, participants completed a dot probe task (MacLeod, Mathews, & Tata, 1986) in which emotional – neutral face pairs preceded the presentation of a probe (the target) which spatial location had to be detected. Results showed that depressed individuals had an attention bias for sad faces and recalled more negative words, however, there were no correlations between the cognitive bias indices suggesting that attention and memory biases operate independently. In line with these initial observations, a recent investigation adopting a similar study design in a sample of non-depressed and formerly depressed individuals under mood induction also found no significant correlations between attention and memory biases (Vrijssen, Van

Oostrom, Isaac, Becker, & Speckens, 2014). Note, that these studies examined correlations between attention and memory using unrelated tasks and different stimulus materials, and as such did not test the dependence between these cognitive processes. Therefore, these studies provide a limited test of the core predictions by the CCBH.

Other studies have used similar stimulus materials across cognitive tasks and bias measures. A first study investigated whether attention biases at different levels of elaboration are associated with memory biases (Koster, De Raedt, Leyman, & De Lissnyder, 2010). Emotional attention was examined via a spatial cueing task (Posner, 1980). On each trial, the task presented a neutral or an emotional cue word followed by a target in the same or opposite location of the cue, and the cue target onset asynchrony (CTOA; the time between onset of cue and onset of target) was manipulated to study the time course of attention bias. After the attention task, explicit memory for previously presented words was tested in an incidental free recall task. The results revealed that subclinically depressed individuals had an attention bias toward negative words only under the conditions that allowed elaborate processing (longer CTOA) and this predicted recall of negative words. The dependence of memory bias on attention is further substantiated by observations from a study in which healthy and subclinically depressed individuals first viewed slides depicting negative, neutral, and positive words in a passive viewing eye-tracking task. This was followed by an incidental recognition test of the displayed words. It was found that the absence of attention bias for positive words, characteristic for subclinically depressed individuals, predicted less accurate recognition of these emotional stimuli (Ellis, Beevers, & Wells, 2011).

Further support for attention – memory bias relations comes from studies linking explicit memory bias to controlled attention (Ellis, Wells, Vanderlind, & Beevers, 2014) and attentional breadth (Wells,

Beevers, Robison, & Ellis, 2010). To study memory in relation to controlled attention (i.e., ability to orient attention to task-relevant material and inhibit irrelevant material), clinically and never depressed individuals were presented with positive and negative word pairs prompting them to orient attention to one word (the target) and to ignore the other item (the distracter) while their gaze behavior was recorded. This was followed by a free recall task to test memory for the encountered stimuli. The results revealed that attention toward negative targets mediated the relation between diagnostic status and memory for negative words, with a stronger relation between attention and memory in clinically depressed individuals (Ellis et al., 2014). Another study linked attentional breadth to recognition memory (Wells et al., 2010). For this purpose, subclinically depressed and non-depressed individuals viewed a series of happy, sad, angry, and neutral facial expressions in an eye-tracking task and completed a subsequent incidental recognition task to assess memory for the faces. The data showed a broader attention focus for angry faces (indexed by larger inter-fixation distances upon viewing these slides) in subclinically depressed compared with non-depressed participants, which was correlated with enhanced recognition of similar faces.

In sum, the current findings suggests that emotional memory can be explained by congruent biases attention when depressed people are exposed to emotional material. However, several studies also reported no evidence for such correlations between attention and memory biases in clinically and formerly depressed samples.

Causal Questions

Attention bias regulates interpretation and memory

One line of studies investigated effects of attention focus via thought-induction procedures (Hertel & El-Messidi, 2006; Watkins & Teasdale, 2004) and cognitive bias modification (CBM) procedures (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013). In a two of

experiments by Hertel and El-Messidi (2006) attention focus was manipulated via a procedure that required participants to elaborate on the meaning of a series of self-focused and other-focused items (e.g., “my character and who I strive to be”, “the physical sensations in your body”). In experiment 1, participants completed an interpretation task in which they created sentences with serially presented homographs (e.g., loaf, reflect) after a self versus other attention focus manipulation. The results indicated that subclinically depressed individuals created sentences revealing more negatively interpreted homographs in the self-focus than in the other-focus condition. In experiment 2, participants were again subjected to the attention focus manipulation after which they were presented with homographs prompting them to report the first words that came to mind. This was followed by an incidental free recall test of the homographs. Subclinically depressed individuals interpreted the homographs more often as personal and also recalled more personally interpreted homographs in the self-focus than in the other-focus condition. The data of the two experiments suggests that heightened self-focused attention in subclinically depressed people leads to more negative and personal interpretations of ambiguous information which transfer to explicit memory.

Another study manipulated attentional focus to investigate the consequences for autobiographical memory specificity in depressed patients (Watkins & Teasdale, 2004). Attention was focused on either the experience (experiential condition) or causes and consequences (analytical condition) described in the focus-induction items (e.g., “the physical sensations in your body”). Before and after the attention manipulation, participants completed an autobiographical memory test (Williams & Broadbent, 1986) in which they were required to generate a specific personal memory in response to positive and negative cue words. It was found that depressed patients engaging in an experiential self-focus (considered as adaptive) recalled less overgeneral memories

after the manipulation procedure, whereas the overgeneral memories persisted in depressed patients engaging in an analytical self-focus (considered as maladaptive).

Taken together, the findings from research manipulating attention focus via thought-induction procedures provides support for the causal influence of attention on interpretation and memory. However, an important limitation of this attention manipulation is that inducing self-focus could also trigger processes such as self-critical thinking that could contribute to the observed relations. More rigorously controlled manipulations of attention focus are required to investigate effects of attention bias on other cognitive processes.

In a recent study by Blaut et al. (2013) participants were either trained to orient attention away from negative words or received no training to test the influence of attention bias on memory. The attention manipulation involved a training variant of the dot-probe task in which a probe (the target) consistently replaces the neutral stimulus, instead of the equal replacement probability in the standard task design (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). It was found that individuals with higher depression levels did not exhibit 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. These findings suggest that attention bias has a causal influence on memory.

Interpretation biases and explicit memory

A second line of research investigated how experimentally induced negative and positive interpretation biases affect memory. A first study tested whether memory for prior ambiguous events change by subsequently established biases in interpretation (Salemink, Hertel, & Mackintosh, 2010). Participants were first presented with ambiguous social scenarios asking them to generate at least one ending for the story. Next, either a positive or a negative interpretation bias was induced

using a bias modification procedure presenting a series of ambiguous stories ending with a word fragment for participants to complete. Completion of this word fragment resolved the ambiguous story in either a positive or negative manner (Mathews & Mackintosh, 2000). After the training, participants completed an incidental cued recall task to test memory for the initial scenarios and their endings. Results showed training-congruent effects on recall of endings of ambiguous scenarios that were presented before the interpretation bias training. Participants trained to interpret ambiguous information as negative recalled more negative scenario endings reflecting their own interpretations prior to the training, and vice versa for positive material.

These observations were extended in another study (Tran, Hertel, & Joormann, 2011). In this study, participants were first subjected to a positive or negative interpretation bias training (similar to Mathews & Mackintosh, 2000), followed by an encoding task in which they solved word fragments of ambiguous stories that remained ambiguous after completion. A subsequent recall task tested participants' memory for the ambiguous scenarios. It was found that trained positive or negative interpretation biases resulted in a training-congruent memory bias for the ambiguous scenarios encountered after training.

A recent study partially replicated these results in a sample of individuals diagnosed with major depression. Employing the same study design as in Tran et al. (2011), it was found that only induced positive interpretation bias had training-congruent effects on the recall for endings (interpretations) of ambiguous scenarios (Joormann, Waugh, & Gotlib, 2015).

As a whole, research on the dependence of memory on interpretation bias suggests that memory is regulated by interpretative biases at encoding and by biases acquired after encoding.

Predictive Magnitude Questions

To date, one study investigated whether prospective changes in depressive symptomatology and recovery status are predicted by multiple cognitive biases in a clinically depressed sample (Johnson et al., 2007). It was found that neither attention nor memory bias was related to recovery status at 9 months follow-up, and only memory for positive information at baseline –and not attention– was associated with lower symptom severity at follow-up. Depressed patients who recalled a higher proportion of positive words at baseline reported less severe symptoms nine months later. These observations suggest that, in the presence of multiple cognitive biases, only some biases (e.g., memory bias) hold promise in predicting depressive symptoms prospectively, whereas other processes (e.g., attention) may be redundant. Although this study examined the predictive value of multiple biases individually, their combined effect was not tested using integrative models (e.g., weakest link, additive models).

Summary

Increasing research on the interplay between emotionally biased cognitive processes has revealed an interesting pattern of findings. First, the dependence of memory on emotional biases in attention is evidenced by observations from cross-sectional research in subclinically and clinically depressed individuals (Ellis et al., 2011, 2014; Koster et al., 2010; Wells et al., 2010) and cognitive training research manipulating attention bias (Blaut et al., 2013). However, under certain conditions, attention and memory biases may operate in parallel without mutual relations in clinically and formerly depressed samples (Gotlib et al., 2004; Vrijnsen et al., 2014), and could differentially affect the longitudinal course of depression (Johnson et al., 2007). Second, heightened self-focused attention alters interpretations of ambiguous information which transfer to memory in subclinically depressed individuals (Hertel & El-Messidi, 2006) and an analytical self-focus

disturbs memory specificity in clinical depression (Watkins & Teasdale, 2004). Third, acquired interpretation biases influence memory for past ambiguous information and memory for subsequently encountered information (Joormann et al., 2015; Salemink et al., 2010; Tran et al., 2011).

Although considerable progress has been made, research in this area is at an early stage and further investigation adopting such an integrative perspective is necessary to advance current knowledge on how multiple biases interact to impact depressive symptoms. First, whereas past studies focused on relations between two cognitive biases, future research will have to integrate a broader set of variables to unlock the complex interplay among processing biases (e.g., how does attention affect interpretation and regulate memory). Second, future research will also have to increase specificity regarding the components and/or systems of the cognitive biases under study (e.g., dependence of implicit memory on attention operations) and study these aspects at different processing stages (e.g., encoding, retrieval). Third, there is no research that has investigated how multiple cognitive biases are modulated by cognitive control difficulties (inhibition, updating, and shifting). Future research may test whether cognitive control acts as an overarching mechanism across multiple cognitive biases at different processing stages. Fourth, there is a need for longitudinal research to investigate the combined impact of multiple processing biases on the course of depressive symptoms. Finally, more integrative research testing association, causal, and predictive magnitude questions should be conducted in a variety of samples, such as in clinically or formerly depressed samples.

Theoretical and Clinical Considerations

Cognitive Frameworks of Depression

Cognitive models of depression are expected to consider interactions among cognitive biases given the empirical evidence for

relations among emotionally biased cognitive processes. The presented empirical findings have several implications. As predicted by most cognitive models (Beck & Haigh, 2014; D. A. Clark et al., 1999; Ingram, 1984; Joormann, Yoon, et al., 2007; Williams et al., 1988), current research confirms the hypothesized relation between attention and memory bias. The data suggests that attention biases at later and not at early processing stages are linked to congruent biases in memory. This finding contradicts predictions by Williams et al. (1997) that depression is not characterized by attention biases and are at odds with Beck's claim that biases emerge also at automatic levels of information processing (Beck & Haigh, 2014; D. A. Clark et al., 1999).

Research showing that negative and positive interpretive biases regulate memory for emotional information suggests that biased information processing could contribute to the consolidation and elaboration of negative schema-content in memory (Ingram, 1984; Joormann, Yoon, et al., 2007; Williams et al., 1988, 1997). However, it is not clear whether the elaborative processing of negative information is driven by improved quality of encoding of negative information, as predicted by the enhanced elaboration accounts (Ingram, 1984; Williams et al., 1988), and/or to impairments in cognitive control, as predicted by impaired cognitive control accounts (Hertel, 1997; Joormann, Yoon, et al., 2007). The current results suggest that emotional biases in attention and interpretation influence emotional memory, which is in line with the idea that cognitive biases maintain negative self-schemas in memory (Beck & Haigh, 2014; D. A. Clark et al., 1999; Ingram, 1984). It is noteworthy, however, that it is still unclear whether there are long-term influences of attention and interpretation bias on memory for emotional information (e.g., how is differentially encoded emotional material consolidated in memory).

As noted earlier, current studies in support of associations between cognitive biases have been conducted mainly in subclinically

depressed samples and findings from research in clinical samples yielded inconsistent results. The present state of the literature only allows researchers to draw conclusions regarding the interplay among cognitive biases at subclinical depressive symptom levels.

State and Trait Effects

As studies on the interplay between biased cognitive processes have been conducted in subclinically, clinically depressed samples, and in formerly depressed people under mood induction, it cannot be determined whether the observed interrelations are trait- or state-dependent effects of depression (i.e., cognitive schemas, personality factors versus mood). Although schema-congruent processing models of depression (Beck & Haigh, 2014; D. A. Clark et al., 1999; Ingram, 1984) assume a direct impact of schemas on cognitive biases, there is also evidence for effects of mood on negative cognitions and cognitive biases. For instance, a study examining diurnal mood variation in relation to autobiographical memories (D. M. Clark & Teasdale, 1982), observed that depressed individuals were more likely to recall unhappy memories at times that are typically associated with more depressive complaints (e.g., mornings). Another study also found that never depressed and formerly depressed individuals in a neutral mood have a positive attention bias, whereas this bias disappeared in formerly depressed individuals in a sad mood (McCabe, Gotlib, & Martin, 2000). These findings suggest that mood state is important in understanding the interplay between cognitive biases in that mood may potentiate trait effects on the interplay between cognitive biases.

To disentangle state from trait factors, the interplay among processing biases can be studied in remitted or formerly depressed samples. In this regard, different cognitive formulations of depression predict that cognitive biases emerge only under certain conditions in this population. Schema models (Beck & Haigh, 2014; D. A. Clark et al., 1999; Ingram, 1984), for example, propose that after a depressive

episode negative schemata remain latent but can be activated at any point in time by distressing situations (e.g., failing an exam). Consequently, remitted depressed individuals will not exhibit biases in attention, interpretation, or memory when not distressed. Impaired cognitive control accounts (Joormann, Yoon, et al., 2007), by contrast, do not specify that negative mood is required to observe biases. This model states that cognitive biases operate as long as cognitive control impairments persist. Indeed, several studies found cognitive control difficulties in formerly depressed individuals (Joormann, 2010) and thus interacting cognitive biases are expected to emerge without induced negative mood states. Future investigation of cognitive biases in remitted depressed people with and without (naturally occurring) negative mood would allow a test of the differential predictions by these cognitive models.

Methodological Considerations

A number of methodological issues seem relevant to the study of the CCBH. The overview of empirical studies shows that present research has investigated interrelations primarily using cross-sectional study designs that include a limited set of cognitive processes, and have applied basic statistical techniques to test relations. Thorough examination of the CCBH requires statistical testing and modeling of direct and indirect relations between multiple variables (e.g., cognitive biases) and latent constructs (e.g., negative schemas). Structural equation modeling, for example, enables theory-driven tests of predictions between multiple variables using methods such as path analysis and structural regression models (Hoyle, 2012). Also data-driven approaches (Borsboom & Cramer, 2013; Hsieh et al., 2010) allow investigation of relations among multiple variables. Here, information is obtained about the structure (i.e., associations among variables) and dynamics (i.e., clusters of variables) of the system in a stepwise manner starting from pairwise correlations between variables.

Another issue concerns the reliability of the experimental paradigms to study emotionally biased aspects of information processing in depression. Several studies examining psychometric properties have provided little support for the reliability of commonly-used cognitive tasks. The dot-probe task, for example, has a low split-half and test-retest reliability, and the attention bias indices drawn from different versions of this task are not always related (Salemink, Van Den Hout, & Kindt, 2007; Schmukle, 2005). Regarding the construct validity, several cognitive tasks that aim to measure the same construct (e.g., attention) are often not correlated (Dalgleish et al., 2003; Mogg et al., 2000). For example, Gotlib et al. (2004) found correlations close to zero between attention bias indexes from a dot probe and emotional Stroop task. By contrast, some studies documented acceptable psychometric features for some tasks (Berna et al., 2011; Griffith et al., 2012; Salemink & van den Hout, 2010). In sum, these observations raise concerns about the psychometric properties of popular cognitive tasks and their bias indexes. Future empirical work should investigate particular task features (e.g., intra-individual variability in voluntary responses on reaction time tasks) and/or the nature of cognitive process (e.g., flexible prioritizing of attention on a trial-by-trial basis depending on thoughts that come to mind) as factors that may account for the poor psychometric properties (Zvielli, Bernstein, & Koster, 2014).

Another issue that demands closer attention is medication use in depressed samples under study. Depressed people, especially in clinical studies, often receive psychopharmacological treatment which could modulate individual cognitive biases (Harmer, Goodwin, & Cowen, 2009). Recent findings indicate that depressed patients taking antidepressant medication have a greater attention bias toward positive stimuli (Wells, Clerkin, Ellis, & Beevers, 2014) and have better memory for positive information (Harmer, O'Sullivan, et al., 2009). Via promoting processing of positive material, it seems plausible that

medication use alters the interplay among cognitive biases, for example, by disrupting a downward spiral with negative content circling through multiple cognitive processes. Hence, researchers need to consider potential effects of antidepressant use when studying interactions between cognitive biases.

Predicting Future Depression

Longitudinal studies have found that biases in cognitive control (Demeyer et al., 2012; Zetsche & Joormann, 2011), attention (Beevers & Carver, 2003; Wells & Beevers, 2010), interpretation (Rude et al., 2010, 2003, 2002), and memory (Asarnow et al., 2014; Bellew & Hill, 1991; Johnson et al., 2007; Reilly-Harrington et al., 1999; Rottenberg et al., 2005; Sumner et al., 2010) are predictive of future depressive symptoms and clinical depression. It is notable that in most studies the proportion of variance explained by these individual cognitive processes is rather small. However, we expect that that cognitive biases have substantial effects on depressive symptoms through their mutual relations and interaction with stressful life events, affecting emotional reactivity to emotional information that may lead to depressive symptoms. Research on the combined impact of multiple cognitive biases on depressive symptoms is currently absent. Future studies on this topic should take into account several issues: (1) variations in the interplay among cognitive biases across different stadia of the depression course, (2) emotion regulation strategies through which multiple cognitive biases may affect depression levels, and (3) interactions with biological vulnerability factors. These issues are discussed in turn.

Variations in the interplay

In examining the predictive value of cognitive biases, potential differences in the interplay between biases across stadia in the course of depression over time should be taken into account. It is plausible that

cognitive biases and their interactions are not static over time. The experience of becoming and being depressed (e.g., increasing sad affect, negative cognitions), for instance, might affect the predictive magnitude of one or more cognitive biases (e.g., memory) and cognitive biases may be more closely connected with an increasing number of depressive episodes (Teasdale & Barnard, 1993). Some studies indicate that the strength of cognitive biases differs in function of depression severity. One study that directly compared the strength of attention biases in individuals with minimal, mild, and moderate to severe depressive symptoms found showed that maintained attention toward negative information was associated with moderate to severe depressive symptom levels (Baert, De Raedt, & Koster, 2010). Also, the impairments in cognitive control may depend on the depressed sample tested. Prior studies have documented valence-specific deficits in cognitive control in a subclinically depressed sample (Koster, De Lissnyder, & De Raedt, 2013), whereas clinically depressed people had global impairments (De Lissnyder et al., 2012). Future longitudinal and cross-sectional research will need to compare the interplay among cognitive biases across different samples corresponding with the phases of the depression course to advance our understanding of how risk factors for depression work together.

Emotion regulation strategies

Current research has generally focused on cognitive biases in relation to emotional reactivity and hallmark symptoms of depression, such as the persistence of sad mood (Clasen et al., 2013). It remains unclear, however, whether emotionally biased cognitive processes have direct effects on depressive symptoms or indirect effects via emotion regulation. The regulatory strategies people use to repair their mood when they experience sadness seems key in differentiating healthy from depressogenic emotional functioning. Depressed individuals tend to ruminate more in response to sad mood or stress, reappraise a

situation's meaning less frequently relative to healthy people, and have difficulties using mood-incongruent recall to repair negative mood (Joormann & Vanderlind, 2014). Rumination involves repetitively analyzing personal concerns, the causes, implications, and meanings of sad mood and distress (Watkins & Nolen-Hoeksema, 2014). Although depressed people do not consider rumination to be unwanted, it worsens mood, impairs stress recovery, and maintains depression (Radstaak, Geurts, Brosschot, Cillessen, & Kompier, 2011; Watkins, 2008). Reappraisal involves altering a situation's meaning (interpretation) to minimize its negative impact. This strategy reduces negative affect and is related to better stress recovery (Jamieson, Nock, & Mendes, 2012; Urry, 2009). Moreover, the accessibility and recall of positive memories is related to higher emotional well-being (Charles, Mather, & Carstensen, 2003; Joormann, Siemer, & Gotlib, 2007; Joormann & Siemer, 2004; Philippe, Lecours, & Beaulieu-Pelletier, 2009).

Novel theoretical models have hypothesized that individual differences in cognitive biases affect the use and effectiveness of regulating strategies to repair or reverse a mood state (Joormann & D'Avanzato, 2010; Koster, De Lissnyder, Derakshan, & De Raedt, 2011). To date, studies have mainly demonstrated that healthy people differ from depressed people in their cognitive biases and emotion regulation, and very few studies have explicitly linked depression-related cognitive biases, emotional experience and regulation. One exception has shown that the relation between cognitive control and depression levels is fully mediated by rumination in remitted depressed individuals (Demeyer et al., 2012). Discovering the mechanisms through which interacting cognitive biases influence emotion regulation strategies and depressive symptoms presents an important goal for future research.

Biological vulnerability factors

Biased cognitive processes are expected to interact with genetic and biological factors (Belzung, Willner, & Philippot, 2015; De Raedt & Koster, 2010; Disner, Beevers, Haigh, & Beck, 2011). Genetic risk factors, such as variations in the serotonin transporter gene (5-HTTLPR), are associated with risk for depression through their effects on social cognition (Homberg & Lesch, 2011). It has been argued that genetic factors are associated with higher levels of vigilance for signs of social threat, which has been found both at the neurobiological (e.g., enhanced amygdala activity on presentation of fearful faces) (Hariri, 2005) and cognitive level (Beevers, Gibb, McGeary, & Miller, 2007; Disner, McGeary, Wells, Ellis, & Beevers, 2014). In addition, genetic factors in interaction with stressors have been linked to reactivity in neural substrates (Caspi & Moffitt, 2006) with a correspondence between abnormalities at the neural system level and distortions in cognitive processes observed in depressed samples (De Raedt & Koster, 2010). For instance, it has been found that upon encountering negative material the increased activation in limbic regions (e.g., amygdala, hippocampus) is related to a reduced activity in specific regions of the prefrontal cortex (e.g., dorsolateral prefrontal cortex, orbitofrontal cortex, anterior cingulate cortex). These latter structures are involved in exerting cognitive control over processing of affective material (Davidson et al., 2002; Whittle, Allen, Lubman, & Yücel, 2006). The study of interactions between attention and memory biases at a neurological level could lead to compelling insight into the interplay between cognitive biases (Chun & Turk-Browne, 2007). The emerging integrative (gene-by-environment) views on depression allow further exploration of the interplay among genes, neurocircuitry, and stress in relation to multiple cognitive biases.

Modification of Cognitive Biases

Knowing how cognitive biases interact may allow us to understand and address some of the difficulties depressed people encounter during therapy in developing new and more flexible ways of thinking (D. A. Clark et al., 1999). Cognitive biases may hinder the effectiveness of verbal information transmission when individuals are severely depressed. That is, concentration, attention, and memory deficits in combination with emotion-specific biases can counteract therapeutic interventions in that encoding, consolidation, and retrieval of information could be strongly favored towards schema-congruent information (Baert, Koster, & De Raedt, 2011).

Given the maintaining role of emotional processing biases, it is important to consider the potential value of targeted cognitive training that can either train neural structures known to be impaired in depression (Calkins et al., 2014; Schweizer et al., 2013; Siegle et al., 2007) or modify emotion-specific biases in attention (Baert, De Raedt, Schacht, et al., 2010; Browning et al., 2012; Cooper et al., 2014; Wells & Beevers, 2010; Yang et al., 2014), interpretation (Blackwell & Holmes, 2010; Bowler et al., 2012; Holmes, Lang, & Shah, 2009; Lang et al., 2012; Menne-Lothmann et al., 2014), or memory (Joormann, Hertel, LeMoult, & Gotlib, 2009; Raes et al., 2009). These cognitive bias modification (CBM) methodologies target specific cognitive processes by exposing participants to experimentally established contingencies during a task designed to encourage the acquisition or attenuation of a certain bias (Koster, Fox, & MacLeod, 2009). Notwithstanding promising findings, the number of CBM studies in depression needs to be extended and enlarged (MacLeod, Koster, & Fox, 2009).

Future improvement of CBM procedures and, in particular, their implementation into clinical practice may benefit from insights gained from studies investigating the CCBH. For example, if the impact of a particular cognitive bias on another cognitive process and

depressive symptoms differs depending on the depression phase, the preferred CBM intervention should be chosen accordingly. Moreover, depending on the precise interplay among cognitive biases in depression (e.g., unidirectional, reciprocal relations), the optimal training program might not only depend on the targeted aspect of information processing (i.e., attention, interpretation, memory, cognitive control) but also on the number of targeted cognitive biases. If various biases operate in a reciprocal manner, one might have to train multiple biases simultaneously to efficiently obtain clinically significant and enduring symptomatic improvement. In this regard, promising findings have been reported by pilot studies combining attention and interpretation bias training in community (Beard, Weisberg, & Amir, 2011) and clinically anxious outpatient (Brosan, Hoppitt, Shelfer, Silence, & MacKintosh, 2011) samples. Both studies observed decreases on self-report or behavioral measures of anxiety. CCBH research has major implications for future CBM applications.

As these training methodologies find their way to clinical practice, they will likely be combined with other approaches to modify biases (e.g., medication, cognitive therapy). Note that different interventions may change biases for emotional information through distinct mechanisms (Browning, Holmes, & Harmer, 2010) and may not always interact as expected. For instance, a study examining effects of citalopram combined with attention bias modification in healthy participants, found that the combined interventions were less effective in inducing a positive bias than each individual intervention (Browning et al., 2011). This warrants specific research on processes affected by cognitive training methods to optimize combinations of treatment strategies.

Conclusion

We argue for an approach that considers interactions between cognitive biases. Current empirical evidence suggests that depression-related biases in attention, interpretation, and memory are related. However, research on this topic is at the beginning stages. Future research could be guided by the outlined research questions and cognitive frameworks of depression. Our understanding of this disorder and its treatment will benefit from research that adopts an integrative perspective to multifactorial risk factors in depression.

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Chapter 2

Attending to Remember

Every day people are confronted with memories of prior emotionally significant events, feelings, and thoughts. For example, a simple job ad in the newspaper may trigger a person's memory of a prior job interview with the attached pleasant and/or unpleasant emotions (e.g., feelings of stress/relief before/after the interview). While healthy persons typically recall more positive aspects (e.g., "I passed the first round of interviews"), depressed persons tend to recall negative aspects tied to that event (e.g., "I failed to address one of the questions"). However, the mechanisms underlying this differential recall of emotional information are currently not well understood. In an attempt to cast light on the processes involved in the encoding and retrieval of emotional material, the experiments reported in this chapter investigated how attention operations modulate encoding and retrieval of emotional interpretations to regulate what is remembered.

Cognitive Biases During Emotional Memory Encoding

Prior research has made considerable progress by showing that emotional biases in attention and interpretation during encoding predict congruent biases in long-term memory (Everaert, Koster, & Derakshan, 2012). However, current understanding of the functional relations among attention, interpretation, and memory biases is limited

in that no research examined these three biases in one single study. We lack a comprehensive insight into the interplay among cognitive biases and the time course of effects. That is, it remains unclear how healthy and depressed individuals direct their attention while elaborating and interpreting emotional information and how this sets the stage for emotional biases in memory. Note, that attention is not a unitary mechanism (Chun, Golomb, & Turk-Browne, 2011) and emotional biases in distinct operations of attention (e.g., attentional selection, sustained attention) might have differential relations with other cognitive processes (e.g., interpretation, recollection). Attention mechanisms that determine which information is processed (i.e., the selection mechanism) 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 but only which information is processed 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 controls what will be remembered (Joormann, Yoon, & Zetsche, 2007; Williams, Watts, MacLeod, & Mathews, 1988). In other words, these models predict that selection mechanisms of attention regulate memory via their influence on interpretation. In another way, attention operations that are involved in how extensively relevant material is processed (i.e., sustained attention) might be strongly related to the extent to which this information is recalled. Similarly, several cognitive models of depression emphasize the role of biases in sustained attention mechanisms during elaboration on emotional information in improving memory for negative material (Ingram, 1984; Williams, Watts, MacLeod, & Mathews, 1997). In explaining emotional biases in memory, these models attribute a central 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.

It is clear that various cognitive frameworks of depression make different predictions on the complex interplay among attention, interpretation, and memory biases. Attentional selection and sustained attention may regulate emotional memory in different ways. To improve understanding of the relations among these biased cognitive processes, we set out two experiments to investigate their interplay during incidental encoding of emotional material.

Experiment 1¹

The first 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 attention and interpretation. Following predictions by cognitive views on depression (Clark, Beck, & Alford, 1999; Ingram, 1984; Joormann et al., 2007; Williams et al., 1988, 1997), we modeled functional relations among distinct attention operations, 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 selective orienting of attention is associated with interpretation bias, which is in turn associated with memory bias. We added links between depression levels and the processing biases to account for depressive symptom levels in explaining associations between biases. In a second path model (Model 2), depression levels are related to negative biases in sustained attention and elaboration processes which are in turn related to

¹ Based on Everaert, J., Duyck, W., & Koster, E.H.W. (2014). Attention, interpretation, and memory biases in subclinical depression: A proof-of-principle test of the combined cognitive biases hypothesis. *Emotion, 14*(2), 331-340. doi: 10.1037/a0035250.

memory bias. To investigate the hypothesis that cognitive biases 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 severity without any relations modeled between cognitive biases (Model 0).

Cognitive processing biases were measured at multiple stages using a sequence of related cognitive tasks. Attention toward emotionally positive and negative material was assessed online using eye movement registration while subclinically depressed and non-depressed participants performed a task to measure interpretative tendencies. Next, we tested explicit memory for the interpretations constructed. An asset of this study design is that the task conditions allow investigation of the online interplay among emotionally biased cognitive processes in a highly controlled, though ecologically-valid, experimental setting. 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. Via a subsequent memory test for the constructed meanings, the paradigm enables a stringent investigation of whether emotional biases in attention operations and interpretation are reflected in memory for the encountered emotional material.

Method

Participants

Seventy-one undergraduate students (62 women, age range: 17-33) were recruited for this study. Recruitment was based on Beck Depression Inventory – II (BDI-II) (Beck, Steer, & Brown, 1996; Van der Does, 2002) scores obtained in a prescreening. Six participants reported use of antidepressant medication. All participants were native Dutch speakers with normal or corrected-to-normal vision and were compensated a course credit or 10 euro.

Depressive symptom severity

The BDI-II measured severity of depressive symptoms via 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 $\alpha=.92$ in this study. At testing, BDI-II scores ranged from 0 to 40, with 39 individuals reporting minimal, 12 mild, 15 moderate, and 5 severe symptom levels. A mean score of 13.56 ($SD=9.57$) was observed.

Stimuli

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 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)². Word position within each scrambled sentence was randomized such that emotional words did not occur next to each other, nor as the first or last word within a scrambled sentence. This controls 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. The positive word was also presented before the negative word in half of the scrambled sentences. Word order criteria imposed on emotional scrambled sentences were

² Word length: $M_{\text{negative}}=8.42$ ($SD=1.90$), $M_{\text{positive}}=8.37$ ($SD=2.12$); Word frequency (log frequency per million): $M_{\text{negative}}=1.07$ ($SD=0.56$), $M_{\text{positive}}=1.22$ ($SD=0.69$).

also applied to neutral target words (e.g., “cinema” and “theatre” in “the I theatre visit cinema often”) in 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 via 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 parameters to index this cognitive process within the current 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 (the areas of interest) served as dependent variables. These parameters are commonly reported indices of attention bias sensitive to individual differences in depressive symptoms (Kellough, Beevers, Ellis, & Wells, 2008; Leyman, De Raedt, Vaeyens, & Philippaerts, 2011) and reflect different attentional mechanisms (Armstrong & Olatunji, 2012). Specifically, the fixation frequency parameter measures (re)orienting of attention and the fixation duration parameter measures sustained attention. Relative bias scores were calculated within-subjects. 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 the relative indices 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 people (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 skipped when a participant did not create a sentence in time during the display part (5% of the trials). Figure 1 presents the flow of events in a single trail.

The task comprised a practice and a test phase. The practice part included 5 trials of neutral scrambled sentences to familiarize participants with the task. The test part 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 presented consecutively in a block to reduce priming effects. A cognitive load procedure was also added to prevent social desirable report strategies. As in previous research with the SST (Rude et al., 2002), 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.

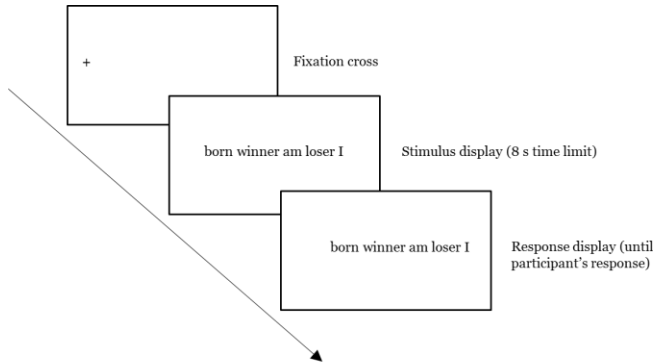


Figure 1. Example trial display.

Memory bias. In the incidental free recall test, participants were asked to recall the sentences that they had constructed during the 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 tracking

The experimental task was programmed in SR Research Experiment Builder and 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) (Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). Areas of interest areas were the negative and positive target words in emotional scrambled sentences and the neutral target words in neutral scrambled sentences.

Procedure

Participants were seated 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 tracking. 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 filled out the BDI-II. The experimental session lasted approximately 70 min.

Statistical analyses

Data analysis comprised two steps. First, we calculated bivariate correlations between cognitive bias indices and depression scores to examine associations among these variables. Next, different path models were fitted by full information maximum likelihood estimation using the SEM package in R (Fox, 2006). As described in the introduction, in Model 0, we used BDI-II scores to predict biases in attention, interpretation, and memory without any relations among these cognitive biases. Model 1 also included a chain from attentional selection bias (relative fixation frequency) over interpretation bias to memory bias. In Model 2, BDI-II scores predict sustained attention biases (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 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.

Table 1. *Descriptive statistics and correlations between cognitive biases and depression.*

Variable	1	2	3	4	BDI-II	M (SD)
1. Attentional selection	–	.49***	.34**	.18	.27*	49.94 (4.36)
2. Sustained attention		–	.22 [†]	.35**	.25*	50.29 (3.34)
3. Interpretation bias			–	.54***	.61***	33.63 (18.41)
4. Memory bias				–	.33**	29.72 (26.72)

Notes. * $p < .05$; ** $p < .01$; *** $p < .001$; [†] $p < .10$.

Results

Associations among cognitive biases

The correlation pattern is supportive for associations among depression scores, attention, interpretation, and memory biases (see Table 1). Individuals with more severe symptoms fixate more frequently and longer on negative information, endorse more negative than positive meanings, and recall relatively more negative sentences. Interestingly, differential correlations emerged between different attentional mechanisms and processing biases in interpretation and memory. Attentional selection bias correlated with interpretation bias but not with memory bias, whereas sustained attention bias correlated with memory bias and marginally significant with interpretation bias. The attention biases 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, $r=.01$, $p>.05$. This indicates that baseline fixation indices, and thus reading times, did not differ with respect to levels of depressive symptom severity.

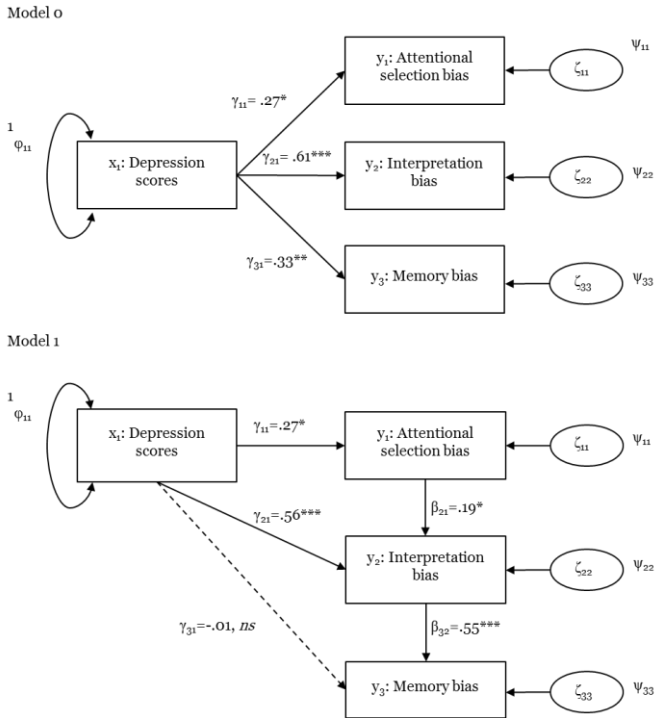


Figure 2. Tested path models including attentional selection mechanisms.

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 between 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, $\gamma_{11} = .27$ ($SE = .12$), $p < .05$, and interpretation bias, $\gamma_{21} = .56$ ($SE = .10$), $p < .001$, but not memory bias, $\gamma_{31} = -.01$ ($SE = .13$), $p = .93$. As expected, biased attentional selection was associated with interpretation bias, $\beta_{21} = .19$ ($SE = .10$), $p < .05$, which in turn was associated with memory bias, $\beta_{32} = .55$ ($SE = .13$), $p < .001$. In 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.

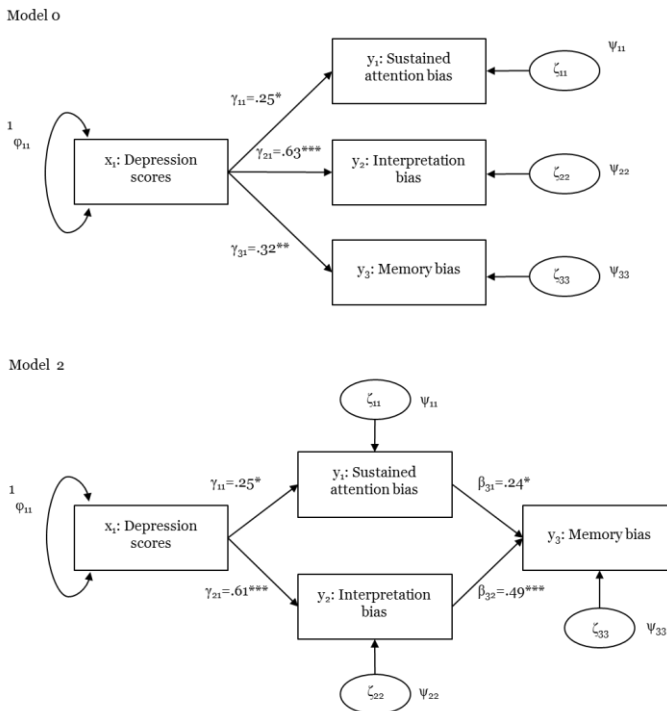


Figure 3. Tested path models including sustained attention mechanisms.

Model 2 versus Model 0. 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 sustained attention bias, $\gamma_{11} = .25$ ($SE = .12$), $p < .05$, and interpretation bias, $\gamma_{21} = .61$ ($SE = .09$), $p < .001$. Both sustained attention, $\beta_{31} = .24$ ($SE = .10$), $p < .05$, and interpretation bias, $\beta_{32} = .49$ ($SE = .10$), $p < .001$, were in turn associated with memory bias. 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

Experiment 1 tested the dependence of emotional memory bias on distinct attention operations and interpretation. The results showed significant correlations between cognitive biases and depressive symptom severity and path analyses revealed that models with the predicted functional relations between processing biases attained good and superior model fits compared to path models without functional relations between biases. These observations provide evidence for the combined cognitive biases hypothesis in a mixed sample of healthy and subclinically depressed individuals. These findings are discussed below.

The present results lend support for associations among depression-linked biases at different levels of processing. As noted, cognitive models of depression (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) and this should have an impact on cognitive tasks and bias measures. The findings demonstrate that individuals with elevated depressive symptoms allocate attention more frequently (attentional selection) and longer (sustained attention) to negative compared to positive material. Also, they make more negative interpretations and recall more negative than positive memories. Interestingly, the 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. These eye tracking parameters thus tap into distinct attention operations (Chun et al., 2011), with the fixation frequency reflecting attentional selection and the fixation duration reflecting sustained attention.

Evidence for the central tenet of the CCBH 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 mechanisms. The modeled paths indicate that attentional selection of negative information is followed by more negative interpretations, 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. Memory bias reflects interpretive choices. Moreover, memory for emotional information was also related to emotional biases in sustained attention. A more severe bias in sustained attention predicted improved memory for negative material. Importantly, the modeled functional relations in Model 1 and Model 2 remained significant when accounting for each bias' relation with depressive symptoms. 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 prior research in that they connect findings from research linking memory to interpretation bias (Hertel &

El-Messidi, 2006; Joormann, Waugh, & Gotlib, 2015; Salemink, Hertel, & Mackintosh, 2010; Tran, Hertel, & Joormann, 2011) and research linking memory to attention biases (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013; Ellis, Beevers, & Wells, 2011; Koster, De Raedt, Leyman, & De Lissnyder, 2010). Thus, the accumulated empirical evidence for the modeled pathways supports competing 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), prompting an integration of the different hypotheses.

Several limitations of this study should be noted. The cross-sectional design precludes conclusions regarding causality because third variables may account for the observed relations. Research should test the hypothesized direction of the modeled pathways via experimental manipulation (see chapter 4). Another limitation concerns features of the study design that forces the use of relative bias indices that compare the processing of positive versus negative material. This is because the emotional scrambled sentences have a different semantic context than the neutral scrambled sentences, which makes it difficult to compare eye movements across emotional and neutral 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 robust markers of depression-associated processing (Shane & Peterson, 2007).

Experiment 2³

Experiment 2 aimed to substantiate the indirect effect of attention bias on memory via interpretation. A sequence of well-established experimental paradigms with similar stimuli across the tasks was used to measure attention, interpretation, and memory biases. This allows investigation of how encountered information is selected throughout several processing stages and a rigorous test of the indirect effect hypothesis.

Method

Participants

Sixty-four undergraduate students (56 women, age range: 17-48) were recruited. Participants were selected based on self-reported depressive symptoms assessed by the Beck Depression Inventory – II (BDI-II) (Beck et al., 1996; Van der Does, 2002) obtained in a screening. Participants received a course credit.

Depressive symptom severity

The BDI-II measures depressive symptom severity through 21 items. The questionnaire has good reliability and validity in both healthy and subclinically depressed samples (Beck et al., 1996; Van der Does, 2002). The internal consistency was $\alpha=.86$ in this study. At testing, BDI-II scores ranged from 0 to 40, with 31 individuals reporting minimal, 15 mild, 14 moderate, and 4 severe symptom levels.

Assessment of cognitive biases

Attention bias. Selective attention was measured via a Posner cueing task modeled after Koster et al. (2010). The task was

³ Based on Everaert, J., Tierens, M., Uzieblo, K., & Koster, E.H.W. (2013). The indirect effect of attention bias on memory via interpretation bias: Evidence for the combined cognitive bias hypothesis in subclinical depression. *Cognition & Emotion*, 27(8), 1450-1459. doi: 10.1080/02699931.2013.787972.

programmed and presented using Inquisit 3 (Millisecond Software LLC., Seattle, WA, USA). On each trial, a black fixation cross was presented for 500 ms at the center of the screen (white background) which was flanked by two black rectangles (2.86° width by 7.63° length). The center of the rectangles was 7.63° from fixation. Next, a cue word (either positive, neutral, or negative in valence; see below) written in uppercase letters (Times New Roman, size 35) was presented for 1500 ms in the middle of one of the rectangles. Then, a target (a black square, $0.67^\circ \times 0.67^\circ$) appeared 50 ms after cue offset (CTOA=1550) in the same (i.e., valid trials) or opposite (i.e., invalid trials) location of the cue word. Participants were instructed to locate the target (left/right decision), as fast and accurately as possible, by pressing the corresponding key on a standard AZERTY keyboard. The target remained on-screen until a response was recorded. The next trial started immediately after a response was registered.

The task presented a 15 practice trials followed by 2 test blocks of each 120 test trials and 6 catch trials. On test trials, there was a 50/50 ratio of valid and invalid trials. Thus, cue words were not predictive of the target's location. Cue words were presented in random order either at the left or right hemifield with an equal number of presentations for each cue word. On catch trials, a digit from 1 to 3 replaced the fixation point for 100ms prompting participants to report the number using the numerical keypad. Catch trials were included to test whether participants maintained gaze on the fixation point throughout the task. Similar to Baert, De Raedt, and Koster (2010), an attention bias index was calculated by subtracting the cue validity (cue validity: $RT_{\text{invalid cue}} - RT_{\text{valid cue}}$) of neutral trials from the cue validity of negative trials ($CV_{\text{negative}} - CV_{\text{neutral}}$).

As cues, 20 positive (e.g., winner, happy) and 20 negative (e.g., loser, sad) cue words were drawn from the interpretation bias task (i.e., the emotional words in the scrambled sentences test; see below) to use

similar stimulus materials across cognitive tasks. In addition, 20 neutral cue words were retrieved from an earlier study (Koster et al., 2010). The cue valence categories were matched on word length (in number of letters; negative words: $M = 7.6$, $SD = 1.60$; neutral words: $M = 8.00$, $SD = 1.49$; positive words: $M = 8.30$, $SD = 1.42$) as indicated by non-significant t -tests (all p -s > .05).

Interpretation bias. A paper-and-pencil scrambled sentences test (SST) (Wenzlaff & Bates, 1998) assessed positive and negative tendencies to interpret ambiguous information. Participants unscrambled sentences using five of the six words to form grammatically correct and meaningful statements (e.g., looks the future bright very dismal). By reporting the unscrambled sentence that comes to mind first (by putting a number above the word), a sentence is resolved in either a positive (e.g., the future looks very bright) or a negative (e.g., the future looks very dismal) manner. Twenty unscrambled sentences designed to tap into depression-relevant themes were retrieved from experiment 1. Participants received 2.5 minutes to complete the task.

A cognitive load procedure was added to prevent social desirable report strategies (see also experiment 1). At start, all participants memorized a 6-digit-number to be recalled at the end of the task. A negative bias in interpretation 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 received 5 min to recall the unscrambled sentences they constructed during the SST as accurately as possible. An unscrambled sentence was coded as a correctly recalled if it matched the sentence reported during the interpretation task in terms of valence (i.e., positive or negative), target word (e.g., bright, dismal), quantifier (e.g., very), and topic (e.g., future). Negative biases in memory were calculated by dividing the

number of recalled negatively unscrambled sentences by the total number of emotional unscrambled sentences recalled.

Procedure

Participants were tested in groups of 20 students in a room designed for testing large groups. They were seated approximately 60 cm from the monitor. All participants started with the Posner cueing task, followed by the SST, and, after a short break (to minimize primacy and recency effects on recall), the incidental free recall test. Then, participants filled out the BDI-II. The experimental session lasted approximately 60 min.

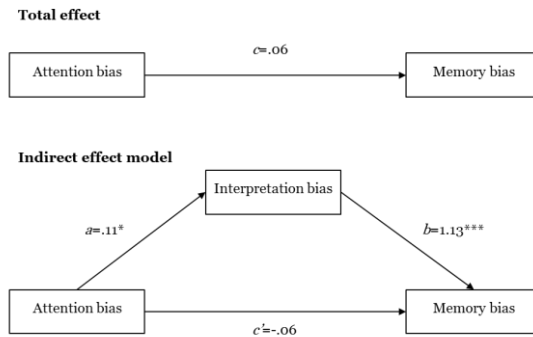


Figure 4. Indirect, total, and direct effects of attention bias on memory bias with interpretation bias as an intervening variable. Notes. * $p < .05$, *** $p < .001$. Unstandardized regression coefficients are displayed.

Data preparation and statistical analyses

Data from the Posner cueing task was trimmed by discarding trials with errors, removing participants ($n=3$) who exhibited a high level of erroneous responding on catch trials ($> 3 SD$ from $M=.04\%$). Also responses reflecting anticipatory ($RTs < 200$ ms) and delayed ($RT > 750$ ms) responding were removed (Baert, De Raedt, & Koster, 2010) as well as outliers (RTs deviating more than $3 SD$ from the M per trial type). Analyses were performed on 96.42% of the data.

The main analysis examined the indirect effect model with attention bias as an independent variable, interpretation bias as an intervening variable, and memory bias as a dependent variable. Figure 4 depicts the tested model. To examine whether the conditions of an indirect effect model were met, we tested the significance of the indirect effect (path $a \times b$), the total effect (i.e., effect of attention bias on memory bias without taking interpretation bias into account; path c) and the direct effect (i.e., effect of attention bias on memory bias variable after controlling for interpretation bias; path c'). Evidence for an indirect effect hypothesis is provided by a significant indirect effect and both non-significant total and direct effects (Mathieu & Taylor, 2006). Note that there are theoretical reasons to expect that both paths c and c' would be non-significant (several cognitive models do not postulate a direct influence of attention on memory bias).

The indirect effect was directly tested using a bootstrapping approach (Preacher & Hayes, 2008). By relying on confidence intervals to determine the significance of the indirect effect, this statistical method avoids problems associated with traditional approaches (e.g., unrealistic assumptions regarding multivariate normality) (Hayes, 2009). In this study, we estimated 5000 bias-corrected bootstrap 95% confidence intervals which should not contain 0 for the indirect effect to be significant.

Results

Correlational analysis

Significant correlations were found between attention and interpretation bias, $r = .25$, $p < .05$, and between interpretation and memory bias, $r = .73$, $p < .001$. Attention bias did not correlate with memory bias, $r = .01$, $p > .05$. Moreover, depressive symptom severity correlated with interpretation, $r = .77$, $p < .001$, and with memory bias, $r = .51$, $p < .001$, but not with attention bias, $r = .19$, $p > .05$.

Importantly, *skewness* (S) and *kurtosis* (K) statistics (z-scores) indicated no substantial deviations from normality for the critical variables: depression levels, $S=1.87$, $K=0.58$, emotional biases in attention, $S=1.28$, $K=0.54$, interpretation, $S=1.98$, $K=-0.73$, and memory, $S=1.42$, $K=-1.71$.

Table 2 presents descriptive statistics for non-depressed (BDI-II<14) and subclinically depressed (BDI-II>13) participants.

Table 2. *Descriptive statistics for depression groups.*

	Non-depressed		Subclinical	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Age	20.41	6.36	19.22	1.54
m/f	3/26		4/28	
BDI-II	8.29	4.04	21.76	6.28
Attention (RTs)				
Negative valid	381	57	372	49
Negative invalid	366	48	363	42
Positive valid	377	54	374	46
Positive invalid	370	57	364	47
Neutral valid	378	55	376	49
Neutral invalid	366	56	363	46
Interpretation				
Relative bias (%)	20.69	16.85	46.73	21.68
no. positive	9.81	3.52	6.64	3.25
no. negative	2.39	1.63	5.97	3.58
Memory				
Relative bias (%)	31.97	35.77	50.14	33.63
no. positive	2.58	1.65	1.88	1.27
no. negative	1.00	1.03	1.82	1.26

Notes. Relative bias indexes compare positive versus negative material; Age data of 4 participants are missing.

Bias-corrected bootstrapping analysis

Bias-corrected bootstrapping revealed that the indirect effect of attention bias on memory bias via interpretation bias was positive (indirect effect coefficient = .12) and statistically different from zero

($p < .05$). The bias-corrected bootstrap confidence interval was entirely above zero, 95% CI = [.004, .270]. Both the total effect, $c = .06$, $t = 0.77$, $p = .44$, and the direct effect, $c' = -.06$, $t = -1.02$, $p = .31$, were not significant. These results support the hypothesis of an indirect effect of attention on memory bias via interpretation bias.

Discussion

Experiment 2 aimed to test specific functional relations between emotional biases in attention, interpretation, and memory in a mixed sample of non-depressed and subclinically depressed individuals. The main finding was that a negative bias in attention has an indirect effect on memory via interpretation. The reported evidence for this indirect effect model lends further support for predictions by cognitive models of depression (Clark et al., 1999; Joormann et al., 2007; Williams et al., 1988). These models postulate that cognitive biases emerge at different levels of processing and influence each other such that a negative bias at one level affects the further processing of this information at other levels. In line with the combined cognitive biases hypothesis, our data suggests that attention to emotional information regulates interpretation of this information which in turn improves memory for this material. Memory bias reflects interpretative choices: when depressed people make more negative interpretations, they are more likely to recall these meanings. Interpretation bias in turn reflects biases in attention in that the selected (negative) information is processed or interpreted.

One finding that needs to be addressed is that there was no relation between depressive symptom severity and attention bias, though the predicted relations between interpretation and memory were observed. This is not in line with the majority of previous studies using an emotional Posner cueing task (De Raedt & Koster, 2010), but note that some researchers also failed to find depression-related attention biases with this task (Koster, Leyman, De Raedt, & Crombez,

2006). Although depressive symptom levels were not related to attention bias, the bias index of this cognitive process was related to congruent biases in interpretation, which was correlated with depression scores. This indicates that, even when not related to depressive symptoms in this study, an emotional bias in attention (which is the gate of all incoming information) is of importance through its influence on other cognitive processes that are related to depressive symptoms.

Some limitations of the present investigation should be acknowledged. First, as in experiment 1, the cross-sectional study design does not allow conclusions regarding the direction of the modeled relations between cognitive biases. Although features of our study design (i.e., temporal sequence of processes and tasks, similar stimulus materials across tasks) optimized conditions to test the indirect effect hypothesis and allow some confidence in the predicted chain of relations between cognitive biases, experimental manipulation is required to stringently test the direction of the effects. In this regard, cognitive bias modification techniques provide the tools to test the postulated causal relations (Koster, Fox, & MacLeod, 2009). For example, to investigate the causal influence of attention bias on interpretation, investigators could manipulate attention allocation (e.g., either by training healthy individuals to attend to positive or negative information, or by training depressed individuals to attend away from negative and toward positive information) and examine differences between the conditions in interpretative tendencies. The data reported here suggests that training an emotional bias in attention would result in congruent biases in interpretation. Our results may provide an impetus for future research to test the direction of the relations through experimental manipulation (see chapter 4).

Other limitations involve the low number of men in this sample. Although the gender distribution was representative for an

undergraduate university college, it may limit the generalizability of the findings to men. Given gender differences in the risk of depression (Nolen-Hoeksema & Hilt, 2009), future research could investigate gender differences in the interplay between vulnerability mechanisms underlying the disorder (e.g., how cognitive biases are involved in gender differences in rumination).

In sum, the findings from experiment 2 converge with results from experiment 1 providing evidence for a model in which attentional selection predicted interpretation bias which was in turn related to memory bias. The data of experiment 2 replicates the indirect effect of attention on memory via interpretation, using a covert attention task to index emotional biases in attention.

Cognitive Biases During Emotional Memory Retrieval⁴

Despite recent advances in knowledge on how attention at encoding regulates emotional long-term memory, little is known about the role of attention during emotional memory retrieval. Prior research on attentional influences on retrieval of emotional material has produced mixed results. One study using a concurrent task to divide attention observed that the emotion-enhanced memory effect was not influenced by divided attention at retrieval (Clark-Foos & Marsh, 2008), indicating that retrieval of emotional material can occur successfully in the absence of focused attention. However, another study reported that the enhancement effect disappeared with divided attention (Maddox, Naveh-Benjamin, Old, & Kilb, 2012), suggesting that emotional memory retrieval is an attentionally-demanding process. Similarly, basic cognitive science studies applying a divided attention paradigm has also yielded inconsistent findings on the role of

⁴ Based on Everaert, J., & Koster, E.H.W. (in press) The interaction between emotional attention, encoding, and retrieval of ambiguous information: An eye-tracking study. *Emotion*. doi: 10.1037/em00000063.

attention during recall of neutral material (Fernandes & Moscovitch, 2000; Naveh-Benjamin, Kilb, & Fisher, 2006).

The extent to which attention during retrieval affects memory may depend on the retrieval process, namely recollection versus familiarity (Dudukovic, Dubrow, & Wagner, 2009). *Recollection* (i.e., retrieval of specific details about the prior occurrence of an item) and *familiarity* (i.e., a sense of having encountered an item without retrieving specific details) rely on at least partly different cognitive and neural mechanisms (Yonelinas, Aly, Wang, & Koen, 2010). The former is attentionally-demanding while the latter can be largely automatic (Jacoby, 1991). Basic research suggest that divided attention during retrieval reduces memory for recollected items but leaves familiarity-based retrieval intact (Hicks & Marsh, 2000).

The distinction between recollection- and familiarity-based retrieval may also be key in emotional memory retrieval: controlled and automatic processes may differentially recruit emotional attention to guide memory search and retrieval. In support of this idea, studies have shown that emotional content (Ochsner, 2000) and affective states (Jermann, Van Der Linden, Laurençon, & Schmitt, 2009) influence memory retrieval by boosting recollection. However, no prior research has tested how attention is deployed toward retrieval cues that are used to guide memory search, and how this relates to the retrieved memory.

Experiment 3

Experiment 3 aimed to examine attention biases toward positive versus negative retrieval cues that are used to guide memory search in an eye-tracking task enabling assessment of attentional allocation to retrieval cues during recollection- and familiarity-based retrieval. It was hypothesized that: (1) attention bias during familiarity-based retrieval will not be related to familiarity memory bias, while attention bias during recollection-based retrieval will be related to recollection memory bias; (2) sustained attention (i.e., assessed by

fixation durations on retrieval cues) and not attentional selection (i.e., assessed by the number of fixations on retrieval cues) bias during recollection-based retrieval will be related to recollection memory bias; and (3) sustained attention bias during recollection-based retrieval predicts recollection memory bias when controlling for encoding bias.

Method

Participants

Forty-nine undergraduate students (45 women; age: 18 – 32 years) were recruited. All participants were native Dutch speakers with normal or corrected-to-normal vision. Participants were paid 10 euro.

Stimuli

Encoding task. A set of 30 emotional and 20 neutral scrambled sentences was drawn from experiment 1. The positive and negative target words presented in each emotional scrambled sentence (e.g., “winner” and “loser” in “am winner born loser a I”) were matched on word class, word length ($M_{\text{positive}}=8.50$, $SD_{\text{positive}}=2.24$, $M_{\text{negative}}=8.50$, $SD_{\text{negative}}=1.91$; $t < 1$, $p > .05$), and word frequency (log frequency per million; $M_{\text{positive}}=1.14$, $SD_{\text{positive}}=0.65$, $M_{\text{negative}}=1.13$, $SD_{\text{negative}}=0.50$; $t < 1$, $p > .05$) using WordGen (Duyck et al., 2004). Word position within each scrambled sentence was randomized with the constraint that emotional words did not occur next to each other, nor as a first or last word within a scrambled sentence. This controls for parafoveal processing of adjoining words and wrap-up effects (Rayner et al., 2000). The positive word was presented before the negative word in 50% of the emotional scrambled sentences. Word order criteria imposed on emotional scrambled sentences were also applied to target words in neutral scrambled sentences (e.g., “cinema” and “theatre” in “the I theatre visit cinema often”). All scrambled sentences were self-referent and six words long.

Memory task. The 30 emotional and 20 neutral target word pairs of the scrambled sentences from encoding served as retrieval cues in the memory task. These ‘old’ items were mixed with an equal number of ‘new’ emotional and neutral distractor word pairs retrieved from the remaining set of scrambled sentences from experiment 1. The ‘new’ emotional target words pairs were matched on word class, word length ($M_{\text{positive}}=8.03$, $SD_{\text{positive}}=2.08$, $M_{\text{negative}}=7.97$, $SD_{\text{negative}}=1.71$; $t < 1$, $p > .05$), and word frequency (log frequency per million; $M_{\text{positive}}=1.33$, $SD_{\text{positive}}=0.74$, $M_{\text{negative}}=1.14$, $SD_{\text{negative}}=0.62$; $t=1.03$, $p=.31$). There were no differences between ‘old’ and ‘new’ negative and positive target words (p -s $> .05$).

Procedure

Figure 5 depicts the trial events of each experimental task.

Encoding task. Participants started with a computerized version of the scrambled sentences test (cf. experiment 1). On each trial, a neutral or emotional scrambled sentence was displayed following fixation (left-aligned to elicit left-to-right reading). While the item was on-screen, participants were instructed to unscramble the sentence into its two semantically different meanings using five of the six words (e.g., “am winner born loser a I” into “I am a born winner” and “I am a born loser”), to elaborate thoroughly on how each statement applied to them, and select the most self-relevant option. In contrast to standard task instructions used in experiment 1, here the instructions encouraged encoding of both sentences with one statement serving as the target cognition in the memory test. The task automatically continued after 30 s or when participants pressed the spacebar. The next trial display presented the scrambled sentence with each word numbered prompting participants to verbally report the sentence selected using the numbers.

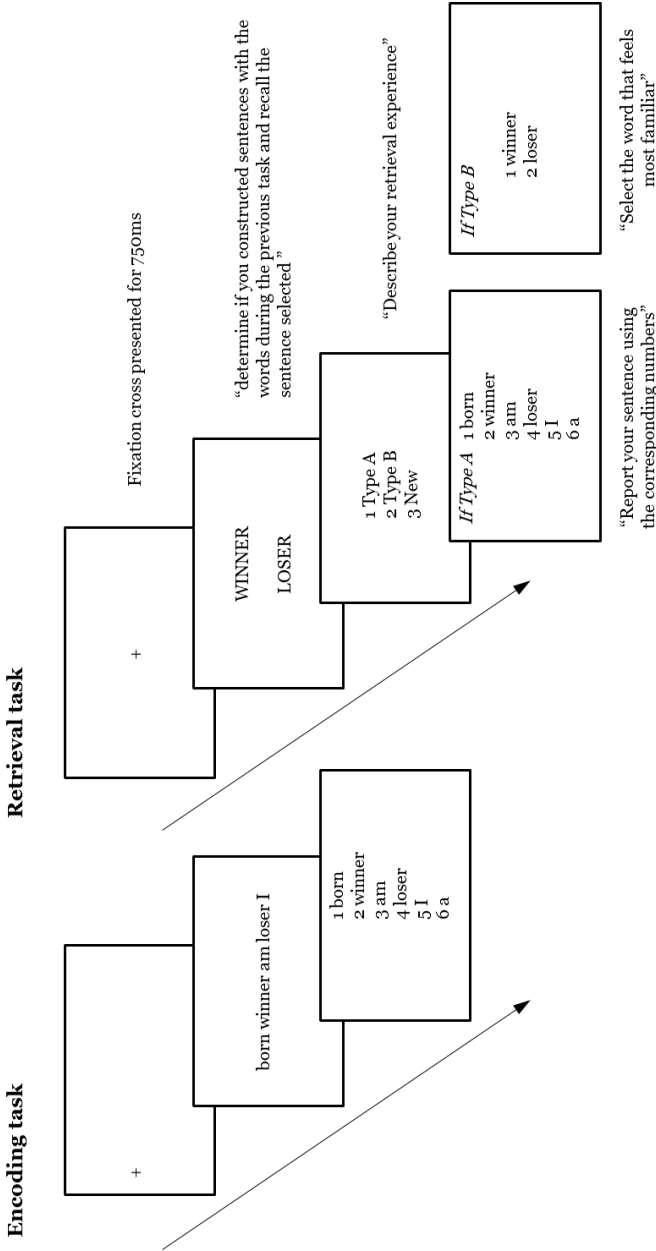


Figure 5. Example of the flow of trial events on the encoding and memory task.

The complete task displayed emotional and neutral scrambled sentences in fixed random order, divided over 5 blocks of each 6 emotional and 4 neutral sentences. No more than two emotional scrambled sentences were consecutively presented to minimize priming effects.⁵ As in prior research, a cognitive load procedure was added to each block to reduce social desirable responses: a six digit number had to be memorized before and recalled after a block (Rude et al., 2002).

Retention interval. After encoding, participants worked for 3 minutes on a digit–symbol substitution test of the Wechsler Adult Intelligence Scale 3th edition (Wechsler, 1997).

Memory task. Next, participants engaged in an incidental memory test. Here, each trial presented two cue words at the same eccentricity (5°) above or below central fixation. Cues were target words from the SST (e.g., “winner” and “loser” on *test trials*) or new words (e.g., “smart” and “stupid” on *distractor trials*). The on-screen position of positive and negative cues was counterbalanced. Test and distractor trials were presented in random order.

While the cues were on-screen, participants were instructed to use the cues to search their memory to determine if they constructed sentences with the words during the previous task and to recall the sentence selected if they thought to have used them before. Participants continued by pressing the spacebar to describe their retrieval experience. Using a remember/know/new paradigm (Tulving, 1985) following recommendations by Migo, Mayes, and Montaldi (2012), participants judged if their retrieval was based on recollection versus familiarity, or whether the word pair was new using following options: “Type A” (i.e., Remember: the word pair cued the recall of details of the sentence selected), “Type B” (i.e., Know: a feeling that the word pair was previously encountered without recalling associated details from the

⁵ Neutral scrambled sentences served as control stimuli, and are not considered here.

prior exposure), or “New”. Next, participants specified the retrieved sentence (for Type A) or selected the cue that triggered the highest sense of familiarity (for Type B). Participants were trained prior to the task to ensure correct understanding of the distinct retrieval experiences.

Attentional bias. Eye movements were recorded when scrambled sentences (encoding task) or retrieval cues (retrieval task) were on-screen to measure attention toward positive and negative words during encoding and retrieval, respectively. This methodology enables online assessment of attention while participants elaborate on self-relevant meanings and use cues to guide memory search.

Eye tracking

Experimental tasks were coded in SR Research Experiment Builder and eye movements were registered with a tower-mounted EyeLink 1000 device (SR Research, Mississauga, Ontario, Canada). Viewing was binocular and eye movements were recorded from the right eye. Fixations were sampled every millisecond and considered when longer than 50ms. Areas of interest were the negative and positive target/cue words in the encoding/memory task.

Assessment of cognitive biases

Attention bias indices reflecting processing of positive over negative material were computed for following variables: (1) attentional selection at encoding; (2) sustained attention at encoding; (3) attentional selection during familiarity-based retrieval; (4) attentional selection during recollection-based retrieval; (5) sustained attention during familiarity-based retrieval; (6) sustained attention during recollection-based retrieval. Bias indices, calculated within-subjects, were based on number of fixations and fixation durations on positive and negative words during the encoding and memory tasks (cf. experiment 1). The number of fixations on positive words was divided by the total number of fixations on positive and negative words to index

attentional selection bias. Analogous calculations led to a relative bias index for fixation duration to index sustained attention bias. These relative bias indices control for inter-individual baseline fixation differences due to inter-individual variability in reading performance.

Table 3. *Memory performance.*

	Negative items		Positive items	
	Remember	Know	Remember	Know
Hits	2.65 (2.31)	0.86 (1.78)	8.96 (3.72)	6.57 (4.15)
False alarms	0.02 (0.14)	0.47 (1.00)	0.31 (0.51)	2.08 (2.23)
Misses	1.04 (1.47)		4.94 (2.25)	

Notes. The mean number of correct rejections was 24.35 (3.03); Scores are means with standard deviations between parentheses.

Encoding bias was indexed by the ratio of selected positively unscrambled sentences over the total selected positive and negative sentences. *Memory bias* indices were computed based on the dual-process signal detection model of recognition conceiving recollection as a threshold process and familiarity as a signal detection process (Yonelinas et al., 2010). The proportion of positive items out of all hits and false alarms was calculated separately for Remember (recollection) and Know (familiarity) reports as well as the proportion of misses and correct rejections (see Table 3). Following Yonelinas et al. (2010), a recollection memory bias index was calculated by subtracting the proportion of false remember (i.e., false alarms, misses) from correct remember (i.e., hits, correct rejections) responses. For familiarity memory bias, d' was computed by subtracting z -transformed false alarm rates from z -transformed hit rates. Higher scores reflect a greater ability to discriminate encoded positive from distractor positive items relative to negative items.

Results

Associations between cognitive biases

Correlations between bias indices were inspected per retrieval process to test associations between attention bias during retrieval and memory bias. Table 4 presents descriptive statistics and correlation coefficients. In line with hypotheses 1 and 2, the correlations between familiarity memory bias and each of the indices of attention bias during familiarity-based retrieval were not significantly different from zero. Regarding recollection-based retrieval, the correlation between memory bias and sustained attention bias was significantly different from zero, while the correlation between memory bias and attentional selection was not. The correlations between memory bias and the attention bias indexes were not significantly different for both familiarity-based ($z=0.65$, $p=.52$) and recollection-based ($z=0.78$, $p=.43$) processes.

Table 4. *Correlations between cognitive bias indices.*

	Encoding			Retrieval		M (<i>SD</i>)
	AB _s	AB _m	EB	AB _s	AB _m	
Encoding						
AB _s (%)	—					50.45 (2.24)
AB _m (%)	.43 ^c	—				51.49 (3.56)
EB (%)	.22	.34 ^b	—			79.59 (13.79)
Familiarity						
AB _s (%)	.32 ^b	.23	.07	—		51.14 (5.87)
AB _m (%)	.27 ^a	.14	-.03	.73 ^d	—	52.26 (7.34)
MB (d')	-.24	-.03	-.25 ^a	-.05	.02	0.00 (1.35)
Recollection						
AB _s (%)	.24	-.10	.02	—		54.50 (6.34)
AB _m (%)	.07	-.09	.25 ^a	.67 ^d	—	55.27 (8.33)
MB (threshold)	.18	-.22	.14	.22	.31 ^b	43.87 (38.84)

Notes. Spearman's rank correlation coefficients are presented; ^a $p<.10$, ^b $p<.05$; ^c $p<.01$; ^d $p<.001$; AB_s=attention selection bias; AB_m=attentional maintenance bias; EB= encoding bias; MB=memory bias.

Note that attentional selection bias during encoding was not significantly different from 50%, $t(48)=1.42$, $p=.16$, indicating positive and negative words were fixated equally. This suggests compliance with the task instruction to consider the positively and negatively unscrambled statements.

Does attentional bias regulate memory recollection?

Hypothesis 3 was tested via a two-step hierarchical regression analysis on recollection memory bias scores with encoding bias and sustained attention bias during recollection-based retrieval entered in the first and second step, respectively. All predictors were z -transformed and the dependent variable showed no substantial deviations from normality (skewedness=-0.57, kurtosis=-2.15). Collinearity statistics were within acceptable limits indicating low levels of multicollinearity (VIF-s<1.08, Tolerance-s>.93). Table 5 presents the statistical models tested. The results showed that encoding bias did not add to the model, $F<1$, $p=.34$. In line with the hypothesis, adding sustained attention bias scores in a second step significantly contributed to the model, explaining 8.9% of the variance in recollection memory bias, $\Delta F(1,46)=4.58$, $p<.05$. The variables included in step 2 accounted in total for 10.8% of the variance, with sustained attention bias ($\beta=.31$, $p<.05$) but not encoding bias ($\beta=.06$, $p=.71$) as a significant predictor.

Table 5. *Hierarchical regression model predicting recollection bias.*

Predictor	<i>b</i>	<i>SE_b</i>	β	<i>t</i>	ΔR^2
Step 1					
Constant	0.48	0.10		4.83 ^d	.019
Encoding bias	0.00	0.00	.14	0.96	
Step 2					
Constant	-0.12	0.30		-0.39	.089 ^b
Encoding bias	0.00	0.00	.06	0.38	
Sustained attention during retrieval	0.01	0.01	.31	2.14 ^b	

Notes. ^a $p<.10$; ^b $p<.05$; ^c $p<.01$; ^d $p<.001$.

Discussion

This study observed that attention bias during recollection-based retrieval predicts accurate recollection of emotional material after controlling for encoding bias. This suggests that retrieval of emotional memories benefits from strategic allocation of attention toward appropriate retrieval cues during memory search. Interestingly, not attentional selection but sustained attention toward positive versus negative retrieval cues may regulate controlled emotional memory retrieval. That is, successful recollection memory depends on how long one focuses attention on a particular cue and not on attentional operations that select cues to guide memory search. Whereas attention may play a role in controlled, recollection-based retrieval, the current findings also indicate that attention toward retrieval cues does not modulate automatic, familiarity-based retrieval. Specifically, the results showed that the correlations between attentional biases at retrieval and familiarity memory bias were not significantly different from zero.

The findings are consistent with prior research indicating that recollection- and familiarity-based processes differentially recruit attention to guide memory search (Hicks & Marsh, 2000) and may explain earlier contrasting findings supporting either automatic (Clark-Foos & Marsh, 2008) or attention-demanding (Maddox et al., 2012) nature of emotional memory retrieval. Moreover, the observations extend prior research on attention biases during encoding in accounting for emotional memory (Talmi & McGarry, 2012) by showing that attention bias also regulates memory during controlled but not automatic retrieval. Sustained attention biases may regulate emotional memory during both encoding and retrieval stages.

The study is not without limitations. First, the high number of female participants limits generalizability of the results to men. Second, measurement of attention via eye-tracking informs on overt attention and provides limited insight into covert attentional shifts. Finally, as in

experiment 1, the study design forces the use of relative bias indices that compare the processing of positive versus negative material. This approach cannot determine whether effects are driven by an emphasis on positive material or a lack of responsiveness to negative material.

In conclusion, this study examined how emotional biases during memory retrieval regulate the recognition of emotional material. The data revealed that the influence of attention during emotional memory retrieval depends on the retrieval process and the attentional operation.

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Chapter 3

Remembering to Attend

What people think, how they feel, and act upon their thoughts and emotions in their daily life is frequently based on prior emotional experiences. It is now well-known that encoding of new learning experiences into long-term memory is modulated emotional biases in attention (Pottage & Schaefer, 2012; Talmi & McGarry, 2012), but surprisingly little known about the reverse effect – how prior emotional learning can guide attention.

Prior learning may contribute to attention via multiple memory systems (Hutchinson & Turk-Browne, 2012). Basic research has demonstrated that explicit long-term memory representations can be used to shift attention toward relevant locations (Becker & Rasmussen, 2008; Brockmole & Henderson, 2006; Stokes, Atherton, Patai, & Nobre, 2012; Summerfield, Lepsien, Gitelman, Mesulam, & Nobre, 2006). For example, detection of transient targets is typically facilitated when viewing previously learned visual scenes that are associated with spatial memories about the target's location (Summerfield, Rao, Garside, & Nobre, 2011). Moreover, there is evidence for the role of implicitly learned associations in guiding attention (Zhao, Al-Aidroos, & Turk-Browne, 2013). Studies on contextual cuing during visual search, for instance, have shown that certain targets (e.g., a rotated T) are more

rapidly detected when embedded within repeated arrays of distractors (e.g., configurations of rotated L's) compared to novel arrays (Chun & Jiang, 2003; Chun, 2000). This suggests that implicit knowledge gained through repetition of target–distractor configurations can guide attention toward the target's location.

If prior learning of non-emotional material can guide attention via explicit and implicit memory systems, emotional learning experiences may also have the ability to alter attentional deployment. Consistent with this hypothesis, several studies in samples of unselected participants have shown that incidental learning of stable relations between neutral stimuli and reward (Anderson, Laurent, & Yantis, 2011; Hickey & van Zoest, 2013) or aversive events (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; Schmidt, Belopolsky, & Theeuwes, 2015) automatically guide attention *toward* stimuli with previously learned associations, mainly affecting attentional capture operations (but see also Van Damme, Crombez, & Notebaert, 2008). Several experiments have also observed the opposite effect, namely early attentional *avoidance* in response to stimuli with emotionally positive and negative associations (Mackintosh & Mathews, 2003). Current research findings converge on the observation that the emotional learning history of a stimulus can modify its attentional priority, but has yielded mixed findings regarding the direction of emotional learning effects on attention.

There is evidence suggesting that the expression of attentional guidance by learned positive or negative associations depends on individual differences factors in emotion processing, such as neuroticism, anxiety, and depression levels. One study showed that learned associations between neutral pictures and negative mental images were more likely to cause attentional interference in high-neuroticism participants during a probe detection task (Fulcher, Mathews, Mackintosh, & Law, 2001). Another study observed that

higher levels of anxiety are linked to memory-based reallocation of attention from locations presenting angry faces to locations depicting happy faces in response to neutral cues (Rohner, 2004). Finally, two recent studies reported that healthy but subclinically depressed individuals oriented attention toward reward-associated stimuli (Anderson, Leal, Hall, Yassa, & Yantis, 2014; Brailean, Koster, Hoorelbeke, & De Raedt, 2014).

Despite recent advances in knowledge on associative learning of emotional material in guiding attention, several issues limit current understanding of this phenomenon. To understand the factors involved in attentional guidance based on prior learning, studies need to assess the effect of the associative learning procedure on the subjective evaluation of the stimuli that are subsequently presented in the attention task. This is important to clarify whether attentional guidance by prior learning is driven by the acquired valence of the stimulus itself or its associations that are activated from long-term memory. While only few studies have reported emotion-congruent effects of neutral – emotional stimulus pairings on ratings of the initially neutral stimuli (Fulcher et al., 2001; Mackintosh & Mathews, 2003), many other studies did not report such data. Moreover, there is a limited number of studies examining depression-related individual differences in attentional guidance by prior learning of positive and negative associations. Addressing this issue seems critical in understanding the relations between the emotional biases in attention and memory that characterize depression (Everaert, Koster, & Derakshan, 2012).

This Investigation

The current experiments aimed to cast light on how emotional learning alters attention allocation by addressing the outlined limitations. Experiment 1 tested whether attention is guided by positive and negative associations and if individual differences in depressive symptoms modulate this effect. In an initial encoding phase, distinct

colors were consistently paired with faces depicting either happy, neutral, or angry expressions while participants performed a gender-discrimination cover task. In a subsequent test phase, participants searched for a target that was framed by either a color that was associated with happy/angry faces versus neutral faces. We expected that (1) higher depression levels would be related to faster target detection times when colors with negative associations framed the target versus the distractor; and (2) higher depression levels would be related to slower target detection times when colors with positive associations framed the target versus the distractor.

Experiment 2 aimed to cast light on the specific attentional operations (attentional capture, attentional disengagement) that may be altered by emotional learning as well as the temporal profile of learning effects on attention. After the encoding phase, participants performed a probe discrimination task in which encoded colors with emotional associations were presented as task irrelevant stimuli. Prior to the presentation of colors that were associated with happy/angry faces versus neutral faces, participants' gaze was anchored to a location at which either a color associated with happy/angry faces or with neutral faces is subsequently presented (Grafton & MacLeod, 2014). Next, a target appeared at the location of the color with emotional associations or the color with neutral associations and participants made probe discrimination decisions. We hypothesized that emotional associations would facilitate detection of targets by affecting attentional capture operations at short exposure durations. Depending on high versus low depression levels, we expected that attention would be captured by stimuli with negative versus positive associations, respectively.

Experiment I

Methods

Participants

Thirty-five participants (27 women, age range: 18 – 35 years) were recruited from the Princeton research pool and participated in sessions lasting 50 minutes. All participants reported normal or corrected-to-normal visual acuity and normal color vision, provided informed consent, and received either \$12 or course credits. The study protocol was approved by the Institutional Review Board for Human Subjects at Princeton University.

Stimuli

Twenty-four face images (unique identities; 12 women) were drawn from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998) based on identification accuracy (>84%), intensity, and arousal ratings (evaluated on 9-point scales) from validation data (Goeleven, De Raedt, Leyman, & Verschuere, 2008). To create positive, negative, and neutral valence categories, eight faces depicting happy [$M_{\text{intensity}}=6.97$ (1.56); $M_{\text{arousal}}=4.18$ (2.06)], angry [$M_{\text{intensity}}=6.54$ (1.67); $M_{\text{arousal}}=3.88$ (1.99)], and neutral [$M_{\text{intensity}}=5.52$ (2.14); $M_{\text{arousal}}=2.36$ (1.40)] expressions were used.

Eight colors were drawn from equally spaced points on a circle (radius 59°) in the CIE $L^*a^*b^*$ color space, centered at $L = 54$, $a = 18$, and $b = -8$. To form arbitrary associations between colors and emotional valence, two of these colors were paired with happy expressions and two colors were paired with angry expressions. The remaining four colors were paired with neutral expressions to provide a baseline measure of the effects of exposure to face-color associations in the absence of emotional valence.

Four additional, independently sampled colors that were never paired with faces were used to probe baseline affective associations in a rating task and serve as lures in a final memory test.

Procedure

Encoding phase

Associations between colors and emotional valence were established via a forward evaluative learning procedure (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010) in which each color was consistently presented with faces drawn from its corresponding valence category (positive, negative, neutral).

Each trial of the encoding phase began with the onset of a circular, uniformly colored disk (radius=8.27°). After 1000ms, a face image (size 11.68° by 11.68°) was superimposed upon the disk. Both stimuli remained onscreen for an additional 2000ms. Following stimulus offset, participants discriminated the gender of the face by pressing one of two response keys ('l' or 'p'). Thus, both the color of the background disk and the emotional expression of the face were completely irrelevant to the primary gender-discrimination task. See figure 1 for a schematic depiction.

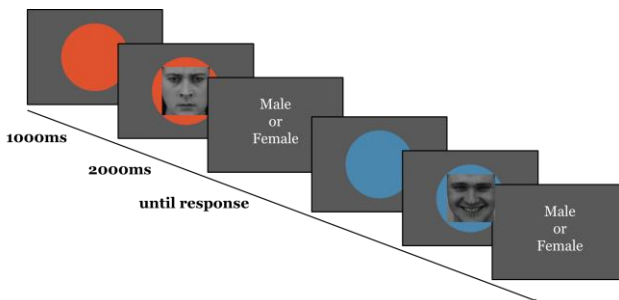


Figure 1. Example of trial flow in the gender discrimination cover task.

Each color-face combination from each of the three valence categories (2 colors × 8 happy faces + 2 colors × 8 angry faces + 4 colors × 8 neutral faces) was presented once during each block (64 trials). Each participant completed six blocks of this task, for a total of 384 trials (64 trials/block × 6 blocks).

Search phase

The consequences of exposure to color-valence associations were assessed in a subsequent search phase. On each trial, two black line segments (0.43° in length) were displayed at the same eccentricity (8.27°) to the left and right of central fixation: one was tilted 45° away from vertical (target) and the other was vertical (distractor). Observers discriminated the position of the target (left or right) by pressing one of two response keys ('i' or 'j'), and the target's position was randomized. In addition, a colored disk (radius= 2.07°) appeared at the location of each line segment. On critical trials, one color was associated with either positive or negative valence ('emotional' colors), and the other was associated with neutral valence ('neutral' colors). Because all colors were equally likely to appear with the target (i.e., valid trial) and distractor (i.e., invalid trial), color was completely task-irrelevant. On control trials, two colors associated with neutral valence appeared with both line segments. The presentation of colors across search displays was counterbalanced, resulting in a total of 192 orientation-discrimination trials, comprising 128 critical trials (32 trials/emotional-color x 4 emotional-colors) and 64 control trials (16 trials/neutral-color x 4 neutral-colors). Figure 2 presents the flow of trial events.

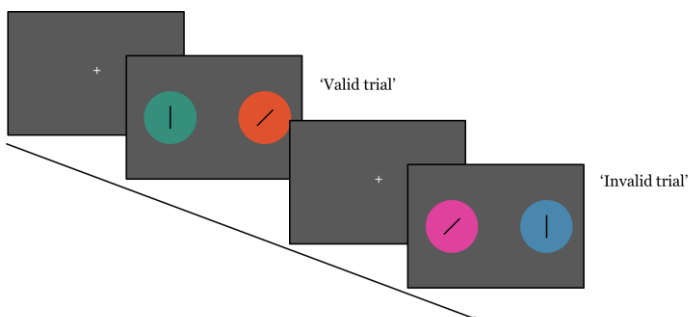


Figure 2. Example of trial flow in the visual search task.

Subjective ratings

To assess participants' explicit preferences for colors, we collected subjective ratings of their 'global feelings' toward each color, evaluated on a 7-point scale from 'very negative' (score of 1) to 'very positive' (score of 7). Participants were instructed to judge their feelings toward the color directly and not take into account any other associations that may come to mind. In total, twelve colors were rated. Eight had been repeatedly presented throughout the encoding and search phases; four were novel colors, to provide a baseline measure of color preference in the absence of specific associations with faces.

Explicit memory test

To assess the nature of the learned associations, we tested participants' explicit memory for the pairing of colors and valence categories. For each color, participants were instructed to judge which of three cartoon face images went best with that color, each of which bore a happy, angry, or neutral expression (e.g., Maratos, Mogg, & Bradley, 2008). If unsure, participants were permitted to report "I don't know". All twelve colors were tested in a randomized order.

Depressive symptom severity

In order to understand how individual differences influenced the nature of affective learning, we administered the Beck Depression Inventory – II (BDI-II; Beck et al., 1996) to measure depressive symptom severity. This questionnaire presents 21 items to be rated on a scale from 0 to 3. The measure has a good reliability and validity in nonclinical samples (Joiner, Walker, Pettit, Perez, & Cukrowicz, 2005). The internal consistency was $\alpha=.94$ in experiment 1 and $\alpha=.91$ in experiment 2. A mean score of 11.48 ($SD=8.89$) on the BDI-II (range: 0-35) was observed.

Apparatus

Participants were seated 70cm from a CRT monitor with a 100 Hz refresh rate. Stimuli were presented against a grey background (RGB: 50/50/50) using MATLAB Release 2013a (MathWorks, Natick, MA) and Psychtoolbox (Brainard, 1997; Pelli, 1997).

Data Preparation

Only correct orientation-discrimination responses were included for analysis (overall accuracy: 90%). Six participants responded incorrectly on more than 20% of the trials (range error rates: 20%-78%) while the mean error rate in the remainder of the group was 4.63% ($SD=2.66$), suggesting low task compliance in these individuals. These individuals accounted for 63% of all errors and were excluded from analyses. The total sample size included in the analyses was 29 observers. Median scores were generated per individual, per trial type, and per emotion category (e.g., valid happy, invalid happy, valid angry, invalid angry, etc.).

Results

Encoding effects on memory and ratings

Percentages of correct responses on the test probing memory for colors associated with happy, $M=50.00$ ($SD=38.49$), $t(27)=2.34$, $p<.05$, and angry, $M=48.21$ ($SD=37.22$), $t(27)=2.16$, $p<.05$, faces were more accurate compared to 33% chance level. Colors paired with neutral faces were recognized by chance, $M=33.33$ ($SD=24.90$).

The subjective ratings of colors associated with angry, $M=4.65$ ($SD=1.33$), happy, $M=4.58$ ($SD=1.19$), and neutral faces, $M=4.75$ ($SD=0.76$), were not significantly different (all t 's <1). The ratings of these 'old' colors were not different from ratings of the four 'new' colors, $M=4.67$ ($SD=.92$), $t<1$.

BDI-II scores did not correlate with indices of memory accuracy or subjective ratings of colors associated with happy, angry, or neutral faces (p -s $>.14$).

Attentional guidance by emotional associations

To test memory-guided effects on attention, a 2 (Valence: happy versus angry) \times 2 (Validity: invalid versus valid) ANCOVA with BDI-II scores as a covariate was conducted on RTs. Results showed no significant main effects of Valence, $F < 1$, $p = .36$, $\eta^2 = .03$ ($M_{\text{negative}} = 587$, $SE = 16$; $M_{\text{positive}} = 593$, $SE = 15$), nor Validity, $F(1, 27) = 1.69$, $p = .21$, $\eta^2 = .06$ ($M_{\text{valid}} = 585$, $SE = 14$; $M_{\text{invalid}} = 595$, $SE = 16$), and BDI-II did not change these main effects: BDI-II \times Validity, $F < 1$, $p = .93$, $\eta^2 = .00$, and BDI-II \times Valence, $F < 1$, $p = .75$, $\eta^2 = .004$. The two-way interaction of Valence \times Validity was significant, $F(1, 27) = 6.32$, $p = .02$, $\eta^2 = .19$, and modified by BDI-II in a three-way interaction: Valence \times Validity \times BDI-II, $F(1, 27) = 8.36$, $p < .01$, $\eta^2 = .24$. These significant interaction-effects suggest general and depression-modulated attentional guidance effects by emotional associations. To break down the three-way interaction, positive and negative associations were considered separately.

For *negative associations*, an ANCOVA on RTs with Validity (invalid versus valid) as a within-subjects factor and BDI-II as a covariate revealed no significant main effect of Validity, $F < 1$, $p = .46$, $\eta^2 = .02$, suggesting no general attentional guidance effects by negative associations ($M_{\text{valid}} = 583$, $SD = 86$; $M_{\text{invalid}} = 591$, $SD = 94$). Also the Validity \times BDI-II interaction failed to reach significance, $F(1, 27) = 3.07$, $p = .09$, $\eta^2 = .10$. For *positive associations*, a similar ANCOVA revealed a main effect of Validity, $F(1, 27) = 9.99$, $p < .01$, $\eta^2 = .27$, with faster RTs on valid, $M = 586$ ($SD = 82$), than on invalid trials, $M = 598$ ($SD = 86$). This suggests a general attentional guidance effect by positive associations. Moreover, the significant Validity \times BDI-II effect, $F(1, 27) = 5.51$, $p < .05$, $\eta^2 = .17$, indicates that this general guidance effect was modulated by depression symptoms.

To follow up on these findings, we computed an attention bias score for positive associations by subtracting RTs on valid trials from RTs on invalid trials. A higher score on this attention bias index suggests a stronger bias toward positive associations. Correlational analysis showed that BDI-II scores were negatively correlated with an attention bias driven by positive associations, $\rho(29)=-.39$, $p<.05$. This suggests greater attentional guidance by positive associations in individuals with lower BDI-II levels while individuals with higher BDI-II levels show less guidance by positive associations.

Interestingly, attentional bias toward stimuli with positive associations was positively related to memory accuracy, $\rho(28)=.45$, $p<.05$. This suggests that better memory for color – happy faces pairings is related to greater attentional bias toward the stimuli with learned associations. Moreover, the correlation between subjective ratings of colors associated with positive faces and attentional bias was not significant, $\rho(28)=.28$, $p=.14$. This suggests that the observed results are driven by the acquired associations and not by the valence of the color itself. Note that the correlations between attentional bias driven by negative associations and BDI-II, $\rho(28)=-.16$, $p=.43$, and to memory accuracy, $\rho(27)=-.15$, $p=.45$, or subjective ratings of colors associated with angry faces, $\rho(28)=.00$, $p=.99$, were not significant.

Discussion

The results from experiment 1 suggest a dissociation between attentional guidance by stimuli with emotionally positive and negative associations. Faster detection times when a target was framed by colors with positive associations than when framed by colors with neutral associations suggest that attention can be guided toward stimuli with positive associations. This was not found for stimuli with negative associations. This general attentional bias

This general attentional guidance effect by positive associations was related to depressive symptom severity levels. Greater attentional

guidance by positive associations occurred in individuals with lower symptom severity and less guidance emerged in individuals with more severe symptoms. Moreover, guidance of attention by positive associations was related to memory for the stimulus – valence associations. The ability to accurately recall the learned positive associations was related to a greater bias toward the stimuli.

Different from previous research applying an evaluative learning procedure to study effects of emotional learning on attention (Fulcher et al., 2001; Mackintosh & Mathews, 2003), the extensive encoding phase in which colors were consistently associated with either positive or negative facial expression did not result in differential subjective evaluations of the colors. Interestingly, individual differences in subjective evaluations of colors with positive associations were not related to attentional bias toward stimuli with such associations. This suggests that attentional guidance by prior learning is not driven by the acquired valence of the stimulus itself but rather its associations that are activated from long-term memory.

To further investigate memory-guided attention effects, we designed experiment 2 to examine which attentional mechanisms (attentional capture, attentional disengagement) are altered by prior learning as well as the temporal profile of learning effects on attention.

Experiment 2

Methods

Participants

Fifty-seven participants (48 women, age range: 18 – 35) with normal or corrected-to-normal visual acuity and normal color vision participated in this experiment. All individuals gave informed consent and received course credits or €10. This study was approved by the ethics committee at Ghent University.

Stimuli and procedure

The experimental procedure was identical to experiment 1 with exception of the attention task. Here, participants performed an cueing task modeled after Grafton and MacLeod (2014). Figure 3 presents the flow of trial events. Each trial started with two black circle outlines (radius= 2.07°) presented at the same eccentricity (8.27°) to the left and right of the center of the screen. A smaller circle (radius= 1.35°) was simultaneously displayed in the center of the left or right black outline with equal frequency. Participants were instructed to direct attention to this smaller circle. After 1000 ms, a horizontal or vertical black line segment (0.43° in length) was shown for 150 ms within the attended region, prompting participants to apprehend the identity of this anchor probe. The anchor probe had a horizontal orientation on 50% of the trials. Next, the two circle outlines were filled with colors drawn from the encoding phase, one disk had associations with either happy or angry faces and the other disk had associations neutral faces. Both colors were presented simultaneously and the color with emotional associations was presented either proximal (i.e., anchor valid trial) or distal (i.e. anchor invalid trial) to initial attentional focus, with equal frequency in either of the two locations. Half of the trials exposed the color display for 100 ms and the other trials exposed the colors for 500 ms. Following offset, a small black line segment (0.43° in length) with a horizontal or vertical in orientation appeared with equal frequency in either the same (i.e., emotional match trial) or opposite (i.e., neutral match trial) location from the color with emotional associations. Participants were instructed to quickly indicate whether this line segment (the target probe) did or did not match the orientation of the anchor probe by pressing the corresponding key. The anchor probe matched the target probe on 50% of the trials. Speed and accuracy of the probe discrimination responses were recorded. The next trial

started after a 1000 ms intertribal-interval. A total of 128 trials were delivered.

Emotional biases in attentional capture were examined by comparing RTs on anchor valid versus invalid trials for emotional match trials. If attention is captured by colors with emotional associations, there should be no difference in RT on anchor valid versus invalid trials when the target probe appears at the location of the color with emotional associations. Delayed withdrawal if attention from colors with emotional associations was investigated by comparing RTs on emotional match versus neutral match trials. If individuals have difficulties disengaging attention from colors with emotional associations, longer RTs will occur on neutral match relative to emotional match trials. Emotional biases in attentional capture and withdrawal of attention were investigated per exposure duration (100ms, 500ms).

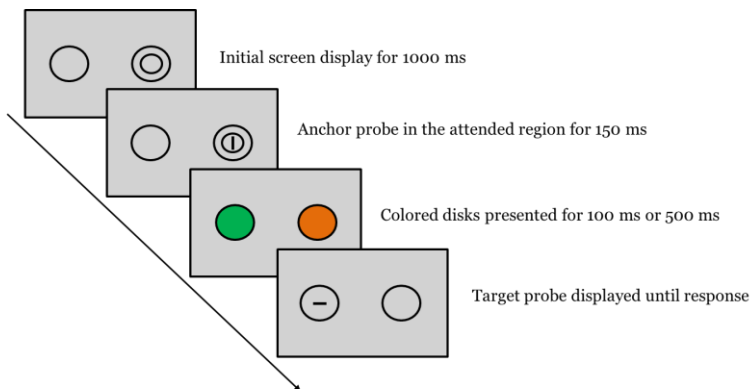


Figure 3. Flow of trial events of the attention task in experiment 3.

Apparatus

Participants were seated approximately 60cm from a CRT monitor with a 100Hz refresh rate. Stimuli were presented against a dark grey background (RGB: 210/210/210) using Psychtoolbox

(Brainard, 1997; Pelli, 1997) for MATLAB Release 2014a (MathWorks, Natick, MA).

Statistical analyses

Three participants were found to be outliers in terms of probe discrimination accuracy on the attention task ($M=46.61\%$, $SD=42.18$, range: 21.88% - 95.31%; remainder of the sample: $M=6.42\%$, $SD=4.29$) and were excluded from analyses. The total sample size included in the analyses was 54 observers. The incorrect probe-discrimination responses were excluded for analysis (overall accuracy: 94.58%) and extreme values deviating more than $3SD$ from the mean on a particular trial type were removed (2.03% of all data points). Mean scores were generated per individual, per trial type, per exposure duration, and per emotion category and cognitive bias indexes were computed. As for experiment 1, attention bias scores were computed per exposure duration and attention mechanisms by subtracting RTs on valid trials from RTs on invalid trials.

Results

Encoding effects on memory and ratings

Color – face expression associations were recognized above 33% chance level for each emotion category: happy, $M=57.41$ ($SD=39.34$), $t(53)=4.56$, $p<.001$, angry, $M=50.93$ ($SD=39.44$), $t(53)=3.34$, $p<.01$, and neutral, $M=51.39$ ($SD=32.73$), $t(53)=4.13$, $p<.001$. Memory for colors associated with happy faces was not different from memory for colors associated with angry faces, $t(53)=1.07$, $p=.29$, or neutral faces, $t(53)=1.37$, $p=.18$. Memory for colors associated with neutral faces was not different from memory for colors associated with angry, $t<1$, $p=.91$. The subjective ratings showed that colors associated with happy faces, $M=4.24$ ($SD=1.00$), were not rated differently than colors associated with angry, $M=4.19$ ($SD=1.18$), $t<1$, $p=.79$, $p=.33$, or neutral faces, $M=4.38$ ($SD=0.86$), $t<1$, $p=.43$. There was also no difference between

ratings of colors paired with angry or neutral expressions, $t(53)=1.01$, $p=.32$.

BDI-II scores were not correlated with memory accuracy nor subjective ratings of colors associated with happy, angry, or neutral faces ($p>.65$).

Attentional guidance by emotional associations

The distribution of BDI-II scores ($M=9.91$, $SD=8.73$, range: 0-35) was skewed ($Z_{\text{skewness}}=3.22$, $Z_{\text{kurtosis}}=0.54$). The ANCOVAs reported below included square root transformed variables. Table 1 presents RTs on non-transformed data.

Table 1. Reaction times on different trial types.

	Negative associations		Positive associations	
	100ms	500ms	100ms	500ms
Anchor valid	850 (173)	821 (192)	841 (153)	826 (190)
Anchor invalid	897 (208)	853 (182)	859 (159)	847 (165)
Emotional match	866 (164)	838 (169)	848 (144)	835 (154)
Neutral match	867 (163)	837 (152)	851 (164)	820 (141)

Note. Means are presented with standard deviations between parentheses.

Attentional capture

A 2 (Valence: happy versus angry) \times 2 (Validity: invalid versus valid) ANCOVA with BDI-II scores as a covariate were conducted on RTs per exposure duration. For *100 ms exposure durations*, results showed no main effects of Valence, $F(1, 52)=1.17$, $p=.29$, $\eta^2=.02$, or Validity, $F(1, 52)=1.43$, $p=.24$, $\eta^2=.03$, and also BDI-II scores did not modify the main effects: Valence \times BDI-II, $F<1$, $p=.65$, $\eta^2=.004$, and Validity \times BDI-II, $F<1$, $p=.80$, $\eta^2=.001$. The significant Valence \times Validity interaction, $F(1, 52)=4.84$, $p<.05$, $\eta^2=.09$, was not modified by BDI-II scores, $F(1, 52)=1.80$, $p=.19$, $\eta^2=.03$. To follow up on the Valence \times Validity interaction, the validity effects were inspected separately for positive and negative associations. Analyses revealed a significant

Validity effect for negative associations, $F(1,52)=4.77$, $p<.05$, $\eta^2=.08$, with faster RTs on anchor valid trials than on anchor invalid trials (see Table 1). This suggests early attentional avoidance of stimuli with emotionally negative associations. The general effect was not modified by BDI-II, $F(1, 52)=1.36$, $p=.25$, $\eta^2=.03$. For positive associations, no effect of Validity, $F<1$, $p=.56$, $\eta^2=.007$, nor an interaction of Validity \times BDI-II, $F(1, 52)=1.37$, $p=.25$, $\eta^2=.03$, was found. The correlational analyses showed that attentional avoidance of stimuli with negative associations was not related to memory accuracy for color – angry face pairings, $\rho(54)=.05$, $p=.72$, nor to subjective ratings of negative colors, $\rho(54)=-.10$, $p=.46$. Also the index of attentional capture by positive associations was not related to memory for color – happy face associations, $\rho(54)=-.07$, $p=.62$, nor to subjective ratings of negative colors, $\rho(54)=-.02$, $p=.87$.

For *500 ms exposure durations*, the results showed no main effects of Valence nor Validity, $F\text{-s}<1$, $p\text{-s}>.69$, and BDI-II scores did not modify the main effects ($F\text{-s}<1$, $p\text{-s}>.55$). The Valence \times Validity interaction, $F(1, 52)=2.07$, $p=.16$, $\eta^2=.04$, nor the three-way interaction with BDI-II, $F(1, 52)=1.86$, $p=.18$, $\eta^2=.04$, was significant. The correlational analyses showed that attentional capture neither by negative nor by positive associations was related to memory accuracy ($p\text{-s}>.17$) or subjective ratings ($p\text{-s}>.06$).

These findings suggest that attention is captured neither by emotionally positive nor by negative associations at longer presentation durations. Attentional capture was also not related to subjective ratings nor memory.

Attentional disengagement

A 2 (Valence: happy versus angry) \times 2 (Match type: emotional-match versus neutral-match) ANCOVA with BDI-II scores as a covariate was conducted on RTs per exposure duration. For *100 ms exposure durations*, results showed no main effects of Valence, $F<1$,

$p=.85$, $\eta^2=.001$, or Validity, $F<1$, $p=.54$, $\eta^2=.01$, and also BDI-II scores did not modify the main effects: Valence \times BDI-II, $F<1$, $p=.40$, $\eta^2=.01$, and Validity \times BDI-II, $F<1$, $p=.57$, $\eta^2=.01$. Neither the Valence \times Validity interaction, $F(1, 52)=2.62$, $p=.11$, $\eta^2=.05$ nor the three-way Valence \times Validity \times BDI-II interaction, $F(1, 52)=2.56$, $p=.12$, $\eta^2=.05$, reached significance. For *500 ms exposure durations*, the results showed no main effects of Valence or Validity, $F_s<1$, $p_s>.59$, and BDI-II scores did not modify the main effects, $F_s<1$, $p_s>.90$. The Valence \times Validity interaction, $F(1, 52)=1.62$, $p=.21$, $\eta^2=.03$, nor the three-way interaction with BDI-II, $F<1$, $p=.32$, $\eta^2=.02$, was significant. For both short and long exposure duration, attentional disengagement by negative nor by positive associations was correlated to memory accuracy ($p_s>.34$). There were also no relations between attentional capture and subjective ratings ($p_s>.24$).

This pattern of results suggest that emotional associations do not modulate attentional disengagement operations neither at short nor at longer exposure durations. Depression levels nor memory accuracy did alter these attentional responses to emotional associations.

Discussion

The results from experiment 2 suggest a dissociation between attentional guidance by emotionally positive versus negative associations. Different from experiment 1, evidence was found for a general effect of emotional learning on attention driven by negative and not by positive associations. The findings suggest that learned negative associations specifically affect early attentional avoidance and not attentional disengagement operations at short exposure durations. Thus, emotionally negative associations may rapidly modulate early attentional mechanisms. Here, no evidence was found that depression levels modulated the effect of emotional learning on attention and memory accuracy was also not related to attentional guidance effects.

Similar to experiment 1, the extensive encoding phase did not alter the subjective ratings of the colors and the individual differences in subjective evaluations of colors were not related to attentional bias indices. Again, these findings suggest that attentional guidance by prior learning is driven by the learned associations with the stimuli that are activated from long-term memory.

General Discussion

In two experiments we investigated whether learned positive and negative associations with stimuli modulate attention allocation in a subsequent search (experiment 1) and cueing (experiment 2) task. The results from both experiments suggest there is a dissociation between attentional guidance by positive versus negative associations. While evidence for attentional guidance by positive associations was found in experiment 1, experiment 2 showed learning effects on attention for negative associations. In line with prior research in samples of healthy individuals, we observed a larger attentional bias toward positive associations and a lower bias toward or avoidance of negative associations (Everaert et al., 2012). As in the majority of prior studies, we also did not find this double bias in one single study. This observation inquires the mechanisms involved in modulating attentional allocation toward stimuli with positive and negative material.

Prior studies that assessed the effect of the associative learning procedure on the subjective evaluation of the stimuli (Fulcher et al., 2001; Mackintosh & Mathews, 2003), suggested that effects of emotional learning on attention can be attributed to the acquired valence of the stimulus itself. Different from these findings, however, both experiment 1 and 2 showed no differential effects of the evaluative learning procedure on subjective liking of the colors associated with positive and negative facial expressions while the learning phase clearly altered performance on the subsequent attention tasks. Also the

individual differences in subjective evaluations of colors with positive associations was not related to attentional guidance by positive or negative associations. This observations suggests that attentional guidance by prior learning is not driven by the acquired valence of the stimulus itself but rather its associations that are activated from long-term memory.

The observed pattern of correlations between memory accuracy and the memory-guided attention biases suggests that different memory systems may be involved in attention guidance by prior emotional learning. While effects of learned positive associations on attention by were related to accuracy on the explicit memory test (experiment 1), this was not found for negative associations (experiment 2). The ability to accurately recall learned positive associations between colors and the paired emotional faces was related to a greater bias in attention toward the colors. This pattern of correlations indicates that different memory systems may have guided attention toward stimuli with positive and negative associations. Given the attention task features of experiment 1 and 2, it seems plausible that attentional guidance by positive associations would have relied more on explicit memory while guidance by negative associations would have relied more on implicit memory. Although the colors with emotional or neutral associations were task-irrelevant in both experiments, the task conditions of the visual search task (experiment 1) may have permitted more time to retrieve the associations with the presented colors whereas the shorter exposure durations in cueing task (experiment 2) allow better measurement of attentional expressions driven by implicit memory. However, the current studies did not include a direct test of implicit memory and further experimentation needs to directly investigate potential differential guidance effects by multiple memory systems (Hutchinson & Turk-Browne, 2012).

Regarding the nature of the particular attentional mechanisms modulated by emotional memory and the time course of such effects, experiment 2 suggested that negative associations specifically modulate early attentional operations at short exposure durations. This findings is consistent with line with prior research documenting effects of prior associative learning on attentional capture (Anderson et al., 2011; Koster et al., 2004; Mackintosh & Mathews, 2003; Schmidt et al., 2015). Similar to observations by Mackintosh and Mathews (2003), the data further suggests that emotional memory has the ability to rapidly bias attention away from stimuli based on prior learning of negative associations. For attentional biases driven by positive associations, however, we were not able to identify the critical attentional mechanisms nor to illuminate the temporal profile. If such guidance effects by positive associations would rely on explicit memory systems, as suggested, than it is possible that attentional disengagement operations would be affected such that healthy people more slowly withdraw from positive material. This hypothesis awaits further research.

Based on prior research evidencing depression-related individual differences in attention allocation toward reward-associated stimuli (Anderson et al., 2014; Brailean et al., 2014), we hypothesized that emotional memory-guided attention would depend on individual differences in depressive symptom severity. In line with this prediction, attentional guidance driven by positive associations was related to depression levels. Individuals with lower symptom levels showed greater attentional guidance by positive associations, while individuals with higher symptom levels showed less attentional guidance by positive associations. However, depression levels did not modulate attentional guidance by negative associations in experiment 2. The lack of depression-modulated effects could be explained by the limited number of participants with elevated depression scores in experiment

2. While 34 % of the participants reported elevated depression levels ($\text{BDI-II} \geq 14$) in experiment 1, only 24% of the participants in experiment 2 reported mild to severe symptoms. Consequently the results from experiment 2 pertain more to healthy emotional functioning rather than depression-modulated distortions in attention.

The current findings have implications for cognitive theories of emotional processing biases which do often not explicitly consider memory contributions to attention bias. In light of prior research showing how certain goals (e.g., making meaning of a situation) guide allocation of attentional orienting and sustained attention toward emotional material (Everaert, Duyck, & Koster, 2014), it seems important to distinguish between goal-based and memory-guided influences on emotional attention. The findings reported here suggest that when processing emotional material, prior learning or memory has an influences on attention allocation. Attentional guidance by emotional memory may alter a different set of attentional mechanisms (e.g., attentional capture) than when current goals regulate attention allocation (e.g., sustained attention, attentional selection). This may be especially true when implicit memory systems guide attention, but may be not different when explicit knowledge is recruited to guide (e.g., goal-based) search for relevant targets. The current pattern of findings prompts theories to consider effects of memory on attention in addition to stimulus-based and goal-based influences. This provides an important challenge for future cognitive models as well as research that draws from these theoretical perspectives.

Several limitations should be acknowledged. A first limitation concerns the number of colors that were paired with emotionally positive or negative facial expressions may have underestimated memory effects on attention. A limited set of colors was deliberately chosen to ensure maximal discriminability between the randomly generated colors. A larger set of stimuli may more accurately reflect the

diversity of stimuli that would receive attention based on prior affective learning. A second limitation concerns the number of participants with elevated depressive symptoms in experiment 1. This may have reduced the likelihood to find modulation of attentional guidance by depressive symptom severity levels. When further investigating how depression levels alter memory-guided attention, a higher number of participants with higher depression levels in the recruited samples is required.

In conclusion, the experiments showed that emotional memory associations with stimuli can modulate attention allocation. Based on prior affective learning, attention can be biased toward stimuli with positive associations and away from stimuli with negative associations. However, there could be a dissociation between attentional guidance by emotionally positive and negative memory associations which could be explained by explicit versus implicit memory systems that differentially contribute to attention allocation.

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Chapter 4

Cause and Effect: Experimental Modification of Attentional Bias

Most research testing relations between emotionally biased cognitive processes inferred mutual influences between cognitive biases from cross-sectional research. Although certain features of the developed study designs optimize conditions to test the effect of one cognitive bias on another process (e.g., temporal order of tasks, similar stimulus materials across tasks) and allow some confidence in the modeled relations between biases, third variables may account for the observed relations. Direct proof of causality requires experimental manipulation of one cognitive bias to track effects on other processes.

Cognitive bias modification methods provide the tools to test the causal role of cognitive biases in psychological disorders. These procedures encourage acquisition or attenuation of an emotional bias via exposure to experimentally established contingencies (Koster, Fox, & MacLeod, 2009). These methods to modify biases in attention (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013) and interpretation (Joormann, Waugh, & Gotlib, 2015; Salemink, Hertel, & Mackintosh, 2010; Tran, Hertel, & Joormann, 2011) have been applied to test the hypothesized influence on emotional memory. The research in this

chapter aims at testing the causal influence of attention bias on interpretation and affective task-switching ability.

Attention Bias Modification Via Single-Session Dot-Probe Training: Failures To Replicate¹

A commonly-used procedure to manipulate attention bias is based on the emotional dot-probe task, originally designed to measure selective attention toward disorder-related material (MacLeod, Mathews, & Tata, 1986). A standard task design simultaneously presents two stimuli (e.g., one disorder-related, one neutral) for a brief duration (e.g., 500 ms) at either side of fixation. After offset, a probe (e.g., an E or F) appears with equal probability at the location of one of the stimuli. Participants are instructed to identify the probe as quickly and accurately as possible by pressing the corresponding button. Negative biases in attention are inferred from faster RTs on trials with probes replacing disorder-related stimuli (i.e., congruent trials) compared to trials with probes replacing neutral stimuli (i.e. incongruent trials). By varying the contingency between the disorder-related stimuli and the probe's location, the standard design can be adapted to induce or reduce emotional biases in attention. Using such an adapted version of the task, MacLeod and colleagues were able to induce a negative bias by consistently presenting the probe at the location of the disorder-related stimulus and, analogously, to reduce a negative bias by presenting the probe at the opposite location (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Interestingly, they found that induction compared to reduction of a negative attention bias increased stress reactivity.

¹ Based on Everaert, J., Mogoase, C., David, D., & Koster, E.H.W. (in press). Attention bias modification via single-session dot-probe training: Failures to replicate. *Journal of Behavior Therapy and Experimental Psychiatry*. doi: 10.1016/j.jbtep.2014.10.011

Building on these initial observations, numerous studies investigated the causal relation between attention bias and symptoms of emotional disorders, including studies examining whether ABM reduces symptoms of anxiety and depression. Effect sizes of attention training on affective symptoms vary strongly across meta-analyses. An early report estimated the effect size of ABM on anxiety in the medium range in nonclinical or subclinical samples, and in the medium-to-large range in clinical samples (Hakamata et al., 2010). Later reports, including a larger number of studies, found only small effect sizes of ABM training in modifying anxiety and emotional reactivity (Beard, Sawyer, & Hofmann, 2012; Hallion & Ruscio, 2011; Mogoșe, David, & Koster, 2014). For depression, meta-analytic evidence suggests no effects of ABM on depressive symptomatology, but note that there is little research testing ABM in depressed samples (Mogoșe et al., 2014). While several recent ABM studies did not produce clinically significant changes (Boettcher, Andersson, & Carlbring, 2013; Carlbring et al., 2012; Julian, Beard, Schmidt, Powers, & Smits, 2012; Rapee et al., 2013), such failures might be due to failures of ABM to change attentional bias at the *group* or *training condition* level (Clarke, Notebaert, & MacLeod, 2014). Yet, there is large variability among trainees in attention bias acquisition following ABM delivery and such *individual differences* may predict anxiety levels (Clarke, Chen, & Guastella, 2012; Clarke, Macleod, & Shirazee, 2008). These observations prompt researchers to consider both the training condition and individual differences level of analysis when evaluating dot-probe ABM effects.

Although ABM seems effective in reducing affective symptoms, the processes through which ABM alters these symptoms need clarification. Decreases in attention bias through training are related to reductions in affective symptoms (Mogoșe et al., 2014), but this does not explain how changes in attention result in a congruent

symptomatic improvement. One process that could account for this is generalization or transfer from the stimuli presented in a controlled experimental training context to non-trained disorder-relevant stimuli and mechanisms closely related to attention that are important to emotional well-being. Transfer effects of dot-probe ABM were investigated by Van Bockstaele, Koster, Verschuere, Crombez, and De Houwer (2012). In their study, participants were trained to attend either toward or away from threatening pictures, but training effects did not generalize to an emotional interference task measuring processes related to attention. These findings contradict earlier observations suggesting that dot-probe training effects generalize to a spatial cueing task, that is, conditions resembling the initial training task (Amir, Beard, Burns, & Bomyea, 2009; Amir, Weber, Beard, Bomyea, & Taylor, 2008; Heeren, Lievens, & Philippot, 2011). Moreover, there is some evidence for transfer of ABM to memory. A study reported that participants with elevated depressive symptom severity trained to orient away from negative words did not show a negative recollection bias which was observed in control individuals (Blaut et al., 2013). In sum, research indicates that dot-probe training effects transfer to new, non-trained stimuli under similar conditions, but provides mixed evidence regarding transfer to other critical processes. The limited insight into the stimuli and processes to which ABM effects transfer warrant further empirical scrutiny.

This section presents three studies to investigate transfer of single-session dot-probe training. In experiment 1, we studied transfer of attention training toward and away from negative material to non-trained stimuli in an affective task-switching task. This task measures the ability to flexibly switch between affective and non-affective processing task-sets, which is a process predictive of trait resilience (Genet & Siemer, 2011). In experiment 2 and 3, we examined transfer of training toward positive and negative material to trained and non-

trained stimuli in an interpretation task requiring individuals to evaluate positive and negative self-relevant meanings. Interpretation bias, a risk factor to various emotional disorders (Mathews & MacLeod, 2005), depends on emotional biases in attention and regulates emotional memory (Everaert, Duyck, & Koster, 2014; Everaert, Tierens, Uzieblo, & Koster, 2013). In keeping with recent ABM research, we investigated effects of training on attention bias and transfer tasks at the condition and the individual differences level. We expected that trained attention biases modulate the flexibility of switching between emotional and non-emotional features of non-trained stimuli and alter interpretation of emotional material.

Experiment I

Methods

Design overview

After the pre-training attention bias assessment, participants were randomly assigned to either a condition in which attention was trained away from negative stimuli (i.e., ‘neutral training’), toward negative stimuli (i.e., ‘negative training’), or the no-training control. Then, participants completed a post-training bias assessment and the affective switching task. All tasks were programmed and presented using Inquisit 3 (Millisecond Software LLC., Seattle, WA, USA). The experiment ended with the questionnaires. The study protocol was approved by the ethical committee at Ghent University.

Participants

Undergraduate students completed either the neutral (n=26), negative (n=23), or no-training (n=25) condition. All participants provided informed consent and received a course credit or 8 euro.

Tasks and measures

Attention training. ABM consisted of a dot-probe procedure modeled after Amir et al. (2008) and Van Bockstaele et al. (2011). On

each trial, a 500 ms fixation was followed by the presentation of two pictures (3.82° height \times 5.06° width) above and below fixation for 500 ms. There was a 3.8° angle between fixation and the picture's center. After offset, a probe (E or F) replaced one picture and participants identified the probe as fast and accurately as possible by pressing the corresponding button. The next trial started 500 ms after a response was registered. Participants were seated 60 cm from the monitor.

There were three different trial types. First, *digit trials* presented numbers from 1 to 6 at the screen's center requiring participants to manually report the digit. This was to check whether participants maintained gaze on fixation throughout the task. Second, *emotional trials* presented negative-neutral picture pairs preceding the probe (e.g., a snake and a dryer). Trials were considered incongruent when a probe replaced the neutral picture and congruent when a probe replaced the negative picture. Third, *neutral trials* presented only neutral picture pairs before the probe (e.g., a book and a cup).

The full ABM procedure comprised four phases. First, a *practice phase* of 24 neutral and 3 digit trials served to familiarize participants with the task. In a subsequent *pre-training phase*, 96 emotional trials (48 congruent, 48 incongruent), 24 neutral trials, and 6 digit trials were presented in random order. Next, in the *training phase*, 288 experimental, 72 neutral, and 18 digit trials were presented in random order equally dispersed over 3 blocks. Depending on the training condition, experimental trials depicted only emotionally congruent ('negative training'), incongruent ('neutral training') or an equal amount of congruent and incongruent ('no-training') trials. In a *post-training phase*, 96 emotional trials (48 congruent, 48 incongruent), 24 neutral trials, and 6 digit trials were presented. As stimuli, 12 negative and 12 neutral scenes were used for assessment and training, and 6 additional neutral scenes were used for practice. The stimuli were

pictures from the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 2008) drawn from Van Bockstaele et al. (2012).

Flexible affective processing. An affective task-switching task was modeled after Genet and Siemer (2011). The task presented emotional pictures against a red or blue background which served as cue to prompt participants to categorize the picture according to the affective (Is the picture content positive or negative?) or non-affective (Is the picture content an animate or inanimate?) rule. For example, participants applied the affective rule when the background colored blue, and the non-affective rule when the background colored red. On each particular trial, one rule was active and the other non-active. Participants were instructed to categorize the picture as fast and accurately as possible by pressing a key. The categories were spatially mapped on to the 'E' and 'F' key. For example, animate and positive were mapped on to 'E' and inanimate and negative were mapped on to 'F'. The category – key mappings and cue – rule linkages were counterbalanced across participants.

Trials were divided into one consistent and one inconsistent block depending on whether responses to the affective and non-affective rule were mapped on to consistent or inconsistent response keys. In the *consistent* block, trials presented only animate positive and inanimate negative pictures such that the response associated with the non-active rule did not interfere with the correct response of the active rule. That is, the presented pictures required participants to press the same key regardless of the cued rule (e.g., 'F' is correct when presented with inanimate negative pictures regardless the cued rule). In the *inconsistent* block, trials presented only inanimate positive and animate negative pictures such that responses associated with the non-active rule interfered with correct responses according to an active rule. Correct categorization responses to the active rule were mapped on to different response keys than correct responses for the non-active rule

(e.g., 'F' is only correct when presented with animate negative pictures and cued with an affective rule) Thus, a correct response required inhibition of the response associated with the non-active rule. After a 60-trial practice with feedback, participants completed 120 consistent trials followed by 120 inconsistent trials. The processing rule alternated randomly within consistent and inconsistent blocks.²

Stimuli. Thirty positive and thirty negative IAPS scenes (Lang et al., 2008) were selected. Half of the positive and negative pictures depicted animate and the other half inanimate scenes.

Questionnaires. Depression severity and trait anxiety were measured with the Beck Depression Inventory – II (Beck, Steer, & Brown, 1996; Van der Does, 2002) and the Spielberger State-Trait Anxiety Inventory – 'trait' version (STAI-T) (Spielberger, 1983; Van der Ploeg, Defares, & Spielberger, 2000). The questionnaires presented a series of statements (21 items in a BDI-II, 20 items in a STAI-T) to be rated on a 4-point rating scale (BDI-II: from 0 to 3; STAI-T: from 1 to 4). Both the BDI-II (Beck et al., 1996; Van der Does, 2002) and the STAI-T (Spielberger, 1983; Van der Ploeg et al., 2000) have good psychometric properties in non-clinical samples.

Data preparation and analytical strategy

Pre and post-training data was trimmed by removing errors, RTs faster than 150 ms and slower than 1500 ms, and outlying RTs ± 3 *SD* from the individual's *M*. All participants performed satisfactory on digit trials and were included. Statistical analyses were conducted on 94% of the data. Affective task-switching task data was trimmed by removing practice trials, errors (9.9%), RTs faster than 250ms and slower than 2500ms (2.5%).

² The affective task-switching task presented an equal number of repetition and switch trials across the training conditions. There were 121.31 (SD=7.98) switch and 118.68 (7.89) repetition trials, $t(72)=1.42$, $p=.16$.

An attentional bias index for the pre and post training phase was computed by subtracting RTs on congruent trials from RTs on incongruent trials (MacLeod et al., 1986), with higher scores indicating a stronger negative bias. Similar to Clark and colleagues, we computed an individual bias acquisition index by subtracting the pre-training from the post-training attention bias score (Clarke et al., 2012, 2008). For the affective task-switching task, repetition and switch trials were identified, and switch costs were calculated by subtracting RTs on repetition trials from RTs on switch trials for the consistent and inconsistent block.³

Table 1. *Sample characteristics experiment 1, 2, and 3.*

	Experiment 1			Experiment 2		Experiment 3	
	Neutral	Negative	No training	Positive	Negative	Positive	Negative
f/m	20/5	*	21/5	10/8	14/6	18/2	16/1
Age	20.70 (1.78)	*	21.76 (3.38)	18.78 (1.86)	19.85 (3.47)	19.10 (2.45)	18.53 (1.55)
BDI-II	8.92 (8.61)	5.78 (5.35)	9.80 (7.11)	7.06 (3.51)	8.50 (3.73)	5.40 (3.98)	6.32 (3.37)
STAI-T	41.16 (10.89)	38.17 (9.14)	43.76 (11.48)	36.72 (5.54)	38.85 (8.73)	34.25 (6.81)	36.79 (7.64)

Notes. Means are presented with standard deviations between parentheses; *data was missing for experiment 1.

Statistical analyses were conducted at the training condition and at the individual bias acquisition level. We first tested ABM effects on attention bias at the condition level via a repeated measures ANOVA on RTs with Time (pre-training versus post-training) and Trial Type

³ RTs on switch trials ($M=1059$, $SD=198$) were significantly higher than RTs on repetition trials ($M=911$, $SD=157$), confirming task-switching costs, $t(72)=15.31$, $p<.01$. Moreover, the task-switching costs on inconsistent trials ($M=220$, $SD=119$) were larger than on consistent trials ($M=102$, $SD=100$), $t(72)=6.75$, $p<.01$.

(congruent, incongruent) as within-subjects variables and Condition (negative, neutral, or no training) as a between-subjects variable. Depending on effective ABM implementation, we followed up by examining transfer effects at the training condition level via condition-specific repeated measures analysis. Next, individual differences in transfer of training were examined via regression analysis. The regression analyses included pre-training attention bias scores (i.e., the natural propensity to attend to emotional material) and individual bias acquisition scores (i.e., the propensity to modify the natural attentional pattern) as predictors of performance on the transfer task, namely the affective task-switching costs on consistent and inconsistent blocks.

Results

Group characteristics

No differences among between conditions were found on age, $F < 1$, BDI-II, $F(2,71) = 2.03$, $p = .14$, or STAI-T scores, $F(2, 71) = 1.70$, $p = .19$. The neutral and no-training condition did not differ on gender ratio, $\chi^2(1) = .21$, $p = .65$. Table 1 present the sample characteristics.

Attention training effects

Repeated measure analysis yielded a main effect of Time, $F(1, 67) = 25.99$, $p < .01$, with faster RTs at post-training than at pre-training (see Table 2). No other main effects were significant (F -s < 1.68). The effect for Time \times Condition, $F(2,67) = 4.280$, $p = .01$, revealed significantly faster RTs at post-training than at pre-training in the neutral, $t(23) = 2.72$, $p = .01$, and no-training, $t(23) = 4.81$, $p < .01$, but not in the negative training condition, $t(21) = 1.06$, $p = .30$. The other interaction-effects were not significant (all F -s < 1).

Transfer to affective task-switching

Transfer effects of attention training were tested at the individual differences level across conditions given the not-successful ABM delivery at the condition level and the substantial variability in

attention bias acquisition scores (across conditions: $M=3.84$, $SD=34.62$, range: $-74 - 98$; see Table 2 for within condition statistics). Regression analysis on consistent task-switching trials yielded no significant model fit $F(2,67)=1.90$, $p=.15$, $R^2 = 5.00\%$, $VIF=1.38$, $T=.72$, without individual effects of pre-training attention bias, $\beta=-.26$, $p=.06$, and individual bias acquisition scores, $\beta=-.08$, $p=.54$. Similarly, neither pre-training attention bias scores, $\beta=-.21$, $p=.13$, nor individual bias acquisition scores, $\beta=.06$, $p=.64$, predicted task-switching costs on inconsistent trials, $F(2,67)=1.20$, $p=.30$, $R^2 = 3.00\%$, $VIF=1.38$, $T=.72$.

Table 2. *Attention training data for experiment 1.*

	Condition		
	Neutral	Negative	No-training
Pre-training			
Congruent	587 (86)	545 (54)	570 (82)
Incongruent	584 (77)	546 (58)	566 (84)
Post-training			
Congruent	559 (73)	533 (61)	523 (70)
Incongruent	553 (71)	536 (66)	516 (75)
ABA	2 (29)	0 (36)	2 (33)
TCC	44%	60%	40%*

Notes. Means are displayed with standard deviations between parentheses; ABA=attention bias acquisition score; Training congruent change (TCC) refers to the percentage of individuals who showed a change in attentional bias score congruent with the delivered training. In the no-training group, 40% exhibited a bias away from threat and the remaining 60% showed an attention bias toward threat compared with baseline.

Discussion

The results yielded no effects of dot-probe ABM in modifying an attention bias at the training condition level, and individual differences in the natural tendency to process emotional material as well as individual differences in attention bias acquisition were not related to affective task-switching costs. This suggests that single-

session ABM might be insufficient to induce and reduce a negative attention bias that could transfer to new emotional stimuli presented in an affective task-switching task.

Experiment 2

Methods

Design overview

After a pre-training attention bias assessment, participants were randomly assigned to a condition in which attention was trained toward either negative (i.e., ‘negative training’) or positive (i.e., ‘positive training’) words. This was to track transfer from ABM to an interpretation task, a scrambled sentences test (SST) (Wenzlaff & Bates, 1998) in which individuals constructed negative or positive sentences from ambiguous information. An SST was administered before the pre-training and after post-training attention bias assessment. Participants completed the questionnaires after the pre-training SST. The study protocols of experiments 2, and 3 were approved by the institutional review board at Ghent University.

Participants

Undergraduate students with minimal depression levels (BDI-II < 14; Van der Does, 2002) at the moment of testing completed either the positive (n=18) or negative (n=20) training condition. All individuals provided informed consent and received a course credit.

Tasks and measures

Attention training. The ABM procedure was identical to experiment 1 with exception of the stimuli (words, not pictures) and presented stimulus pairs (negative-positive pairs, not negative-neutral pairs). Emotional trials were considered incongruent when probes replaced positive words, and congruent when probes replaced negative words. There was 2° vertical distance between the words.

Stimuli. Forty-eight word pairs were selected for the ABM task. Each pair corresponded with positive and negative words from a scrambled sentence (e.g., ‘bright’ and ‘dismal’ in ‘looks the future bright very dismal’; see below). Word pairs of the pre-training SST were presented in the pre-training phase and word pairs of the post-training SST were presented in the training and post-training phase. All stimuli were displayed in white uppercase letters against a black background. Twelve neutral-neutral word pairs corresponded with target words from a SST used in an earlier study (Everaert et al., 2014).

Transfer task and questionnaires. The SST assessed interpretation bias. Presented with a scrambled sentence (e.g., “looks the future bright very dismal”), participants form grammatically correct and meaningful self-relevant statements by using 5 of the 6 words. Reporting the first sentence that comes to mind, all solved items have a positive (e.g., “the future looks very bright”) or negative (e.g., “the future looks very dismal”) meaning. Two matched sets of 24 scrambled sentences were drawn from Everaert, Duyck, et al. (2014) as a pre- and post-training measures. At each assessment, participants solved as many sentences as possible within 3.5 minutes. A cognitive load procedure was applied to reduce social desirable responses (Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002). Participants memorized a 6 digit number before which they had to recall after the test. The number of sentences solved in a negative versus positive manner served as an index of interpretation bias. The questionnaires were identical to experiment 1.

Data preparation and analytical strategy

Pre- and post-training data were trimmed by removing errors (4.80%), RTs faster than 150 ms and slower than 1500 ms (< 1%), and RTs \pm 3 SDs from the individuals’ mean score (1.30%). All participants performed satisfactory on digit trials and were included. A change index for interpretation bias was computed by subtracting pre-training from

post-training biases scores *across* training conditions. The analytical strategy from experiment 1 was applied.

Results

Group characteristics

The negative and positive training condition were not significantly different regarding mean age, $F(1, 36)=1.36$, gender ratio, $\chi^2(1)=.85$, $p=.36$, $p=.25$, BDI-II, $F(1, 36)=1.50$, $p=.23$, nor STAI-T, $F<1$, $p=.38$, scores (see Table 1).

Table 3. *Attention training and interpretation data for experiment 2 and 3.*

Variable	Experiment 2		Experiment 3			
	Positive	Negative	Positive		Negative	
	500 ms	500 ms	750 ms	1000ms	750ms	1000 ms
Pre-training						
Congruent	515 (45)	556 (58)	604 (91)	588 (81)	655 (106)	653 (108)
Incongruent	507 (43)	556 (52)	599 (90)	584 (93)	659 (105)	645 (116)
SST	25 (16)	27 (19)	19 (15)		19 (12)	
Post-training						
Congruent	504 (40)	537 (57)	600 (62)	594 (63)	618 (81)	614 (73)
Incongruent	501 (42)	536 (49)	602 (68)	598 (61)	618 (78)	607 (70)
SST	24 (14)	23 (16)	14 (14)		19 (15)	
ABA	4 (20)	-1 (30)	8 (54)	8 (50)	-4 (50)	1 (52)
TCC	50%	55%	55%	65%	42%	47%

Notes. Means are displayed with standard deviations between parentheses; ABA=attention bias acquisition score; TCC=Training congruent change.

Attention training effects

Analysis yielded a main effect of Time, $F(1, 36)=6.17$, $p=.02$, with faster RTs at post-training, $M=520$ ($SD=48$), than at pre-training assessment, $M=534$ ($SD=50$). The main effect of Condition, $F(1, 36)=7.31$, $p=.01$, indicated that individuals in the positive training condition responded significantly faster, $M=507$ ($SD=43$), compared to individuals in the negative training condition, $M=547$ ($SD=54$). The

effect of Trial Type, $F(1,36)=2.15$, $p=.15$, and all interaction-effects were not significant (F -s <1.10). Table 3 presents the RT data.

Transfer to interpretation bias

As in experiment 1, there was substantial variability in attention bias acquisition scores (across conditions: $M=1.77$, $SD=25.28$, range: $-49.41 - 54.51$; see Table 3 for within condition statistics) warranting analysis of transfer of training at the individual bias acquisition level across conditions ($N=38$). Regression analysis showed that neither pre-training attention bias scores, $\beta=.06$, $p=.77$, nor individual bias acquisition scores, $\beta=.12$, $p=.58$, predicted the change in interpretation bias, $F<1$, $p=.85$, $R^2=1.00\%$, $VIF=1.62$, $T=.62$.

Discussion

The ABM procedure did not induce a positive or negative attention bias and pre-training attention bias as well as individual bias acquisition scores were also not related to interpretation bias. To optimize the attention training, the procedure in experiment 3 presented emotional faces to elicit stronger emotional reactions compared to verbal stimuli (Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013), and extended stimulus presentation durations to allow longer elaboration on the stimuli presented (Mogg & Bradley, 2005).

Experiment 3

Methods

The experimental procedure was identical to experiment 2.

Participants

Undergraduate students with minimal depression levels (BDI-II < 14) (Van der Does, 2002) completed to the positive ($n=20$) or negative training ($n=19$). All participants provided informed consent and received course credits or 8 euro.

Tasks and measures

Attention training. The ABM task from experiment 2 was modified such that after fixation two face expressions appeared at the left and right side from fixation for either 750 ms or 1000 ms (to test the effect of elaboration time). Within trials, the face pairs depicted a happy and a sad expression from the same actor or two neutral expressions from different actors. The horizontal distance between the center of the pictures was 12.37° (picture size $9.33^\circ \times 9.33^\circ$). After offset, a probe (an E or F) prompted participants to identify the letter by pressing the corresponding button. The next trial started 500 ms after a response was recorded. Features of the ABM task were identical to experiment 1. An equal number of trials presented the stimuli for 750 ms and 1000 ms in each phase.

Stimuli. Face expressions were drawn from the Karolinska Directed Emotional Faces database (Goeleven, De Raedt, Baert, & Koster, 2006). Based on the hit rates (>80%), intensity, arousal ratings (evaluated on 9-point rating scales), and identity (same actor for happy and sad faces), 24 happy (intensity: $M=6.39$, $SD=1.64$; arousal: $M=3.85$, $SD=1.98$), 24 sad (intensity: $M=6.14$, $SD=1.66$; arousal: $M=3.67$, $SD=1.76$), and 18 neutral (intensity: $M=5.11$, $SD=2.17$; arousal: $M=2.51$, $SD=1.47$) faces were selected.

Transfer task. Interpretation bias was measured using the SST. Two versions of each 20 items were used as pre- and post-training assessment. Participants received 2.5 minutes to complete the test and again a cognitive load procedure was applied.

Data preparation and analytical strategy

Errors, RTs faster than 150 ms and slower than 1500 ms, as well as individual outliers ($\pm 3SD$ from M) were removed from the pre- and post-training data. All participants performed satisfactory on digit trials and were included. Analyses were ran on 96% of the data. The analytical strategy was identical to experiment 2.

Results

Group characteristics

Training conditions did not differ on age, $F < 1$, $p = .41$, gender ratio, $\chi^2(1) = .21$, $p = .65$, BDI-II, $F < 1$, $p = .44$, nor STAI-T, $F(1,37) = 1.20$, $p = .28$, scores (see Table 1).

Attention training effects

Analysis on RTs for trials presenting stimuli for 750 ms revealed no significant main or interaction effects of Time \times Condition, Trial Type \times Condition, or Time \times Trial Type. Also the crucial effect of Time \times Trial Type \times Condition was not significant (all F -s < 2). The analysis on RTs for trials with 1000 ms durations yielded no effects of Time, $F < 1$, Trial Type, $F < 1$, or Condition, $F(1,37) = 2.97$, $p = .09$. The interaction-effects of Time \times Condition, $F(1,37) = 2.65$, $p = .11$, Trial Type \times Condition, Time \times Trial Type, and Time \times Trial Type \times Condition were also not significant, F -s < 1 . Table 3 presents RT data.

Transfer to interpretation bias

Individual differences in transfer were examined across conditions ($N = 39$) given the considerable variability in attention bias acquisition (across conditions: for 750 ms duration: $M = 2.00$, $SD = 52.13$, range: $-127.25 - 146.63$; for 1000 ms duration: $M = 4.76$, $SD = 50.42$, range: $-131.38 - 121.25$; see also Table 3 for within condition statistics). For 750 ms presentation durations, regression analysis on change scores of interpretation bias ($F < 1$, $p = .67$, $R^2 = 2.20\%$, $VIF = 1.59$, $T = .63$) revealed no predictive effects of pre-training attention bias, $\beta = -.17$, $p = .41$, nor individual bias acquisition scores, $\beta = -.16$, $p = .45$. For 1000 ms presentation durations, regression analysis showed that not pre-training attention bias, $\beta = -.18$, $p = .35$, but individual bias acquisition scores, $\beta = -.46$, $p < .05$ predicted the change in interpretation bias. However, the model with the two predictors had no significant fit: $F(2, 36) = 3.05$, $p = .06$, $R^2 = 14.5\%$, $VIF = 1.60$, $T = .63$.

Discussion

The dot-probe training induced neither a positive nor a negative attention bias. Again, pre-training attention bias scores and individual differences in attention bias acquisition were not related to performance on the interpretation transfer task.

General Discussion

Three experiments investigated transfer effects of single-session dot-probe attention training procedures to manipulate emotional biases in attention allocation. In contrast to prior research reporting effective modification of attention through dot-probe training in healthy samples (Hakamata et al., 2010; Hallion & Ruscio, 2011; Mogoşe et al., 2014), we found –across three studies– no evidence that dot-probe ABM can induce or reduce attention biases via a single-session training. Although the applied training procedure closely resembled procedures that have effectively implemented ABM (Amir et al., 2008; Van Bockstaele et al., 2011), we did not find changes in attention bias at the training condition level in response to training toward negative, positive, or away from negative with various stimulus materials (i.e., emotional scenes, words, facial expressions) and stimulus presentation durations (500ms, 750ms, 1000ms). Thus, the present findings add to recent research that did not replicate successful ABM delivery (Boettcher et al., 2013; Carlbring et al., 2012; Rapee et al., 2013).

When inspecting individual differences in bias acquisition, we consistently observed a large inter-individual variability both within and across training conditions indicating that attention bias changed in accordance to the contingency of the dot-probe procedure in a subset of the trained individuals, in the conducted experiments varying from 42% to 65%. Analogous to studies indicating that such individual differences predict changes in anxiety (Clarke et al., 2012, 2008), we tested whether individual differences the natural propensity to attend to emotional

material (i.e., pre-training attention bias scores) and the propensity to modify the natural attentional pattern (i.e., individual bias acquisition scores) were related to individual differences in performance on the transfer tasks. We found no evidence for transfer of attention training at the individual differences level of analysis. Individual bias acquisition scores were not related to congruent biases on an affective task-switching task presenting new, non-trained stimuli. This finding seems to be in contrast with prior studies reporting transfer from dot-probe training to new stimuli presented in a spatial cueing (attention) task (Amir et al., 2009, 2008; Heeren et al., 2011). Furthermore, we found no evidence for transfer of individual training effects to interpretation bias. Individual bias acquisition scores were not related to performance on an interpretation test presenting trained (experiment 2) or non-trained (experiment 3) stimuli. This is surprising in light of prior research showing that interpretation mediates the relation between attention and memory bias (Everaert et al., 2014, 2013). Moreover, the pre-training attention bias scores did not predict affective task-switching costs nor the change in interpretation bias. This suggests that an individual's natural tendency to allocate attention to emotional material, measured before attention training, is not related to performance on transfer tasks tapping into cognitive processes related to attention.

What factors may explain the variability in ABM response and modulate transfer? Effective ABM delivery may depend on attentional control (Eysenck, Derakshan, Santos, & Calvo, 2007), that is a person's ability to exert top down control to focus attention on stimuli appearing at the probe's location and to inhibit attention on stimuli at the opposite location. Individuals with better attentional control may benefit more from ABM training which might enhance transfer of training. The role of top down attentional control in bottom up (dot-probe) ABM and how this alters transfer requires future investigation. A second factor that

could moderate training and transfer are emotion regulation strategies. Such strategies (e.g., reappraisal, rumination) do not only involve attention toward information that matches one's concerns, but also cognitive processes to which ABM might transfer, in that way moderating (transfer of) training. Interestingly, research found that high ruminators trained to attend toward positive material showed a stronger positive bias after training (Arditte & Joormann, 2014), and observed a close relation between rumination and emotional biases in interpretation (Mor, Hertel, Ngo, Shachar, & Redak, 2014). Future studies may consider trait differences in emotion regulation when evaluating ABM training and transfer effects. A last factor concerns the limited reliability of the dot-probe task to measure attention bias, as such jeopardizing detection of training and transfer (Salemink, Van Den Hout, & Kindt, 2007; Schmukle, 2005). Particular task features (e.g., intra-individual variability in voluntary responses) and the nature of attention (e.g., flexible prioritizing on a trial-by-trial basis depending on thoughts that come to mind) could explain the low reliability. Its causes need to be identified to optimize future task designs.

Several limitations of the experiments conducted should be acknowledged. A first limitation is the lack of effective ABM implementation at the condition level. Although examining transfer via individual bias acquisition scores is informative, transfer of ABM may need to be retested after effective ABM delivery at the condition level. A second limitation is the measurement of affective task-switching after the ABM procedure in experiment 1. Although this avoids adverse consequences of long experimental sessions, we cannot rule out that there were pre-existing differences between training conditions. Measuring switching ability before and after training would enable a more rigorous test of transfer from ABM to this process. Another limitation concerns the order of cognitive tasks after training delivery. In all experiments, participants completed a transfer task after post-

training bias assessment which could have reduced ABM effects on the transfer task. However, proof of change in attention bias and transfer is essential to draw conclusions on training effects and how they transfer (Van Bockstaele et al., 2011). Of final note, the limited range of psychopathology may have obscured training and transfer effects. Studies by Blaut et al. (2013) and Arditte and Joormann (2014) observed training or transfer at higher levels of depression or rumination. The restricted range of affective symptoms in the experiments limits exploration of such moderation effects.

In conclusion, three experiments provide no evidence for single-session dot-probe ABM to effectively manipulate attention biases toward negative, away from negative, or toward positive stimuli at the training condition level. The large individual variability in attention bias acquisition was not related to the performance on transfer tasks of flexible affective processing and interpretation. Future research may need to investigate factors that moderate attentional plasticity in response to dot-probe ABM to optimize conditions for effective implementation and transfer of training.

Ability and Tendency Processes During Ambiguity Resolution⁴

A wealth of empirical research has provided evidence for depression-related emotional biases in attention and interpretation. Whereas healthy people are biased toward positive material, depressed people allocate attention disproportionately more to negative compared with positive or neutral material (De Raedt & Koster, 2010; Peckham, McHugh, & Otto, 2010) and draw more negative than positive meanings on ambiguous information (Wisco, 2009). These biases in attention and

⁴ Based on Sanchez, A., Everaert, J., De Putter, L., Mueller, S., & Koster, Ernst H. W. (in press). Emotional attention during instructed and uninstructed ambiguity resolution in relation to depressive symptoms. *Biological Psychology*.

interpretation seem closely related. Attention biases modulate encoding (Everaert et al., 2014) and retrieval (Everaert & Koster, 2015) of emotional interpretations drawn on ambiguous material. At present, however, the nature of attention and interpretation biases is not well-understood.

Some theoretical models of depression (Clark, Beck, & Alford, 1999; Ingram, 1984; Williams, Watts, MacLeod, & Mathews, 1997) assume that emotionally biased cognitive processes reflect processing tendencies driven by schemas. Schemas refer to a coherent set of memory representations gravitating around beliefs about the self and others (e.g., “I am a failure”). The knowledge represented in these schemas could be recruited in automatic and goal-driven or strategic ways to guide attention allocation and interpretation while processing new emotional information. In support of this hypothesis, some studies have shown that prior learning experiences can shape attention allocation toward emotionally congruent material (Anderson, Laurent, & Yantis, 2011; Fulcher, Mathews, Mackintosh, & Law, 2001; Hickey & van Zoest, 2013; Rohner, 2004; Schmidt, Belopolsky, & Theeuwes, 2015).

Other cognitive views on depression (Hertel, 1997; Joormann, Yoon, & Zetsche, 2007; Joormann, 2010) propose that cognitive biases reflect regulatory deficits in cognitive or attentional control. Attentional control refers to a person’s ability to exert top down control to focus attention on task-relevant stimuli and to inhibit attention toward task-irrelevant stimuli. Here, emotional biases in attention toward negative material would reflect deficits in cognitive control processes, such as deficient cognitive inhibition of negative material in working memory. In support of this notion, research has demonstrated such depression-related difficulties in inhibition and attentional control (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; Derakshan, Salt, & Koster, 2009; Goeleven et al., 2006; Joormann, 2004).

While schema-based and impaired cognitive control accounts of depression differ with respect to their prediction regarding the nature of emotional biases in attention and interpretation, both theoretical perspectives have received some empirical support. At present, however, a direct test comparing how tendency versus ability processes are involved in the interplay between attention and interpretation biases during elaboration on emotional material has yet to be conducted. This lingering issue motivated the current study.

Experiment 4

To illuminate the nature of attention and interpretation biases related to depression, empirical tests could be derived from defining features of tendency-driven versus ability-driven processes with respect to the malleability of the cognitive biases in attention and interpretation. If attention and interpretation biases reflect processing tendencies, then these biases could be overridden by verbal instruction and/or top-down control (Hertel, 1994). Alternatively, if these biases are related to a reduced ability to control or regulate emotion processing, than they would be less malleable via verbal instruction and thus require more sophisticated interventions to modify the processing biases (Calkins, McMorran, Siegle, & Otto, 2014; Siegle, Ghinassi, & Thase, 2007).

The present study aimed to investigate relations between depressive symptom severity, attention bias, and interpretation bias while distinguishing between processing tendency and ability processes based on assumptions regarding their malleability. We adapted a recently designed method to model attention – interpretation relations (Everaert et al., 2014) to tap into tendency and ability processes. The original study design involved the use of eye tracking (to measure attention bias) while participants performed a scrambled sentences test (to measure interpretation bias). This test requires participants to create self-referent statements using five of the six presented words (e.g., “I am a born winner” derived from the item “born I winner am

loser a”). In this study, participants with varying depressive symptom levels took part in two different lab sessions in which they completed a processing tendency (session 1) or ability (session 2) version of the scrambled sentences test. In the tendency version, participants were asked to report the first unscrambled sentence that came to mind (i.e., to assess individual differences in the *tendency* to interpret ambiguous information in a negative or positive manner). In the ability version, participants were asked to unscramble all emotional sentences in a positive manner (i.e., to assess individual differences in the *ability* to draw positive meanings on ambiguous information). Modeling relations between depressive symptom severity, attention bias, and interpretation bias, several cognitive models (Ingram, 1984; Joormann et al., 2007; Williams, Watts, MacLeod, & Mathews, 1988) and prior research (Everaert et al., 2014, 2013) point out that depression-related biases in attention can regulate the process of interpretation. Therefore, we hypothesized that attention bias (indexed by the relative fixation time on positive versus negative words in a scrambled sentence) would mediate the relation between depressive symptom severity and interpretation bias (indexed by the number of positively versus negatively unscrambled sentences). We expected such an indirect effect for both tendency and ability processes.

Method

Participants

Fifty-two undergraduate students (39 women; age range: 17-27) with a broad range of Beck Depression Inventory – II (BDI-II) (Beck et al., 1996; Van der Does, 2002) scores were recruited. All participants were native Dutch speakers with normal or corrected-to-normal vision. They provided informed consent and were paid 15 euro. The study was approved by the faculty review board at Ghent University.

Depressive symptom severity

The BDI-II assessed depressive symptom severity. On 21 items rated on a four-point scale, respondents indicated the extent to which they suffered from depressive symptoms in the past two weeks. This measure has good reliability and validity in both healthy and depressed samples (Beck et al., 1996; Van der Does, 2002). The internal consistency was $\alpha=.94$ in this study. At testing, a mean score of 9.85 ($SD=9.39$; range: 0-37) was observed, with 38 individuals reporting minimal, 5 mild, 6 moderate, and 3 severe symptom levels.

Stimuli

A total set of 43 Dutch scrambled sentences (24 emotional, 19 neutral sentences) was drawn from the stimulus pool designed for a prior study (Everaert et al., 2014). All scrambled sentences were self-referent and six words long. Each emotional scrambled sentence presented one positive and one negative target word (e.g., “winner” and “loser” in “am winner born loser a I”). Target words were matched between valence categories on word length, word class, and CELEX-based word frequency using WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004).⁵ There were no differences between negative and positive target words on these lexical variables (F -s < 1). To control for parafoveal processing of adjoining words (Schotter et al., 2012) and wrap-up effects (i.e., differential reading times for sentence-final versus sentence-internal words; Rayner, Kambe, & Duffy, 2000), word position within each scrambled sentence was randomized with the constraint that emotional words occurred neither next to each other nor as the first or last word within a scrambled sentence. In addition, the positive word was presented before the negative word in exactly half of

⁵ 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): $M_{\text{negative words}} = 1.02$ ($SD_{\text{negative words}} = 0.47$), $M_{\text{positive words}} = 1.04$ ($SD_{\text{positive words}} = 0.62$).

the emotional scrambled sentences. Criteria employed for 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 sentences.

Assessment of cognitive biases

The experimental task design was modeled after Everaert et al. (2014) who used a combination of an interpretation task (a computerized version of the Scrambled Sentences Test; SST; Wenzlaff & Bates, 1998) with online measurement of attention bias (via eye tracking).

The basic experimental design. Each trial of the SST started with the presentation of a fixation cross at the left side of the screen until participants fixated the point for 200 ms. The following *stimulus display* presented either a neutral or an emotional scrambled sentence. Each scrambled sentences occurred at the center of the screen on a single line in black mono-spaced lowercase Arial (font size 25pt) against a white background. Participants were instructed to mentally unscramble the sentences to form a grammatically correct and meaningful statement using five of the six words (e.g., “I often visit the theatre” in a neutral trial; “I am a born winner”, in an emotional trial), as quickly as possible. Upon completion, participants pressed a button to continue to the *response trial part*. Here, each word of the scrambled sentence was presented with a number prompting participants to report their unscrambled solution to the experimenter using the corresponding numbers (to reduce socially desirable responding). The response display was presented until response or for maximum of 8000 ms.

After a 3-trial practice phase with only neutral scrambled sentences, participants started the test phase. The test phase presented 40 scrambled sentences dispersed over 5 blocks with 3 blocks of only emotional sentences and 2 blocks of only neutral scrambled sentences.

The neutral blocks were always presented between emotional blocks to reduce priming effects (i.e., emotional – neutral – emotional – neutral – emotional). Each block randomly presented 8 scrambled sentences. Interpretation bias was indexed by the number of positively versus negatively unscrambled sentences over the total correctly completed emotional (positive and negative) sentences (see the ‘cognitive bias indices’ section).

While participants performed the SST, their gaze behavior was recorded during the *stimulus display* trial parts of the task via eye-tracking. This enabled online measurement of visual attention while participants actively selected competing positive and negative stimuli (e.g., “winner” and “loser” in “am winner born loser a I”) to elaborate on the target item relevant to the process of making meaning (e.g., “I am a born winner” versus “I am a born loser”). Eye movement registration provides sensitive parameters (e.g., fixation times) to index emotional biases in attention allocation in such a reading context (Rayner, 1998).

Tendency versus ability processes. As noted in the introduction, the malleability of the processing biases through top-down control is, by definition, a distinguishing feature of tendency-driven versus ability-driven processing biases. It is proposed that tendency processes can be overridden by verbal instruction whereas ability-related regulatory impairments are less malleable via instruction. This defining feature can be used to pit these different views on the nature of cognitive biases against each other. In this study, we used this basic feature to create two different versions of the SST: one version to index individual differences in the *tendency* to interpret ambiguous information in a negative or positive manner, and the other variant to assess individual differences in the *ability* to draw positive meanings on ambiguous information.

The tendency and ability version of the basic task design only differed with regard to the task instructions provided to the participants.

In the tendency version, participants received the standard task instructions and were asked to report the first unscrambled sentence that came to mind. In the ability version, participants were instructed to unscramble all emotional sentences to create grammatically correct and positive self-statements in the emotional blocks and to follow standard task instructions during neutral blocks. The tendency and ability version of the SST were completed in two separate experimental sessions. All participants first completed the tendency version and one week later the ability version. The long time interval prevented memory-effects in the second session (even after a short retention interval participants recalled <7 unscrambled solutions in a previous study; see Everaert, Duyck, et al., 2014).

The same set of scrambled sentences was used in each version of the SST. Note that the blocks of trials were presented in a different order between the sessions to control for serial position effects. Three types of block combinations across the two SST versions were constructed. We ensured that the emotional and neutral blocks in the first session did not appear in the same order in the second session. Participants were randomly presented with one of the three possible block combinations.

Cognitive bias indices

The same indices of attention and interpretation bias were computed for the tendency and the ability versions of the SST. Following calculations were made for each task variant. To obtain a measure of *attention bias*, we considered the total fixation time (i.e., the sum of the duration across fixations) on the positive versus negative target words in the emotional scrambled sentences (i.e., the areas of interest). This parameter is a commonly reported index of attention bias that is sensitive to individual differences in depressive symptom severity (Armstrong & Olatunji, 2012; Ellis, Beevers, & Wells, 2011; Everaert et al., 2014). A relative bias score (i.e., positive versus negative)

was calculated within-subjects (Everaert et al., 2014). The total fixation time on positive words was divided by the total fixation time on emotional (positive and negative) words in the emotional scrambled sentences. Note that this relative index controls for inter-individual baseline fixation differences due to inter-individual variability in reading performance.

For *interpretation bias*, a positive bias index was computed by dividing the number of positively unscrambled sentences by the total number correctly completed emotional (positive and negative) sentences.

Eye tracking

Participants' eye movements were recorded using a Tobii TX300 eye-tracker system. This system employs a dual-Purkinje eye-tracking method (Crane & Steele, 1985) and samples eye-gaze coordinates at 300 Hz (e.g., a coordinates' estimation every 3.3 ms). Both stimuli presentation and eye movements' recording were controlled by E-prime Professional software (Schneider, Eschman, & Zuccolotto, 2012). The eye-tracking system synchronized automatically with the program at the start of each trial. Participants were seated approximately 60 cm from the eye tracker capture. Eye movement signals were converted to visual fixation data by using E-prime extensions for Tobii (i.e., Clearview PackageCalls). Visual fixations were considered when longer than 100 ms. Areas of interest were the negative and positive target words in each emotional scrambled sentence.

Procedure

The study involved two separate experimental sessions. In the first session, participants provided informed consent and completed the BDI-II. This was followed by the tendency version of the SST, which was combined with eye tracking. A 9-point grid calibration procedure

was repeated before each emotional block of the SST, drifts from proper calibration were checked at the start of each trial, and the system was recalibrated when necessary. The experimenter recorded the participants' verbal responses (i.e., the coded unscrambled sentences) manually without providing feedback. Participants were given the opportunity to take a short break after each test block to ensure optimal concentration. In the second experimental session, one week later, participants completed the ability version of the SST, which was again combined with eye-tracking. We adhered to the same protocol as in the first session. Each experimental session lasted between 20-30 min.

Statistical analyses

The data-analytic strategy comprised two steps. First, we inspected bivariate correlations between depressive symptom severity (BDI-II scores) and biases in attention (percentage of the total fixation time spent on positive words) and interpretation (percentage of positively unscrambled sentences) during tendency and ability processes. This was done to investigate associations between the variables under study. Second, to examine how tendency and ability processes in attention and interpretation biases operate in depression, we tested a mediation model in which attention bias intervenes as mediator in the relationship between depressive symptom severity and interpretation bias. Note that model building was based on theoretical hypotheses by cognitive models (Ingram, 1984; Joormann et al., 2007; Williams et al., 1988) and prior research findings (Everaert et al., 2014, 2013).

We tested the mediation model separately for tendency and ability processes using a bootstrapping approach (Preacher & Hayes, 2008). By relying on confidence intervals to determine the significance of the indirect effect, this statistical method avoids problems associated with traditional approaches (e.g., unrealistic assumptions regarding multivariate normality) (see Hayes, 2009). We examined the

significance of the total effect (i.e., effect of depressive symptom severity on interpretation bias without taking into account attention bias; path *c*), the direct effect (i.e., effect of depressive symptom severity on interpretation bias after controlling for attention bias; path *c'*), and the indirect effect (i.e., effect of depressive symptom severity on interpretation bias via attention bias; path $a \times b$). The estimated 5000 bias-corrected bootstrap 95% confidence intervals should not contain 0 to be significant (Preacher & Hayes, 2008).

Table 1. *Correlations between dependent variables and descriptive statistics.*

	1	2	3	4	<i>M</i> (<i>SD</i>)
BDI-II	-.32*	-.75**	-.31*	-.19	9.85 (9.39)
Processing tendency					
1. Attention bias	–	.30*	.08	.20	52.06% (3.18)
2. Interpretation bias		–	.15	.26+	69.87% (23.76)
Processing ability					
3. Attention bias			–	.32*	52.82% (3.58)
4. Interpretation bias				–	96.89% (6.99)

Notes. BDI-II = Beck Depression Inventory – II; + $p < .10$; * $p < .05$; ** $p < .01$.

Results

Correlational analysis

Table 1 presents the correlations between depressive symptom severity and emotional biases in attention and interpretation for tendency and ability processes.

Processing tendency. There were negative correlations between depressive symptom severity and both attention and interpretation biases, suggesting that lower depressive symptom severity levels are linked to more positive emotional biases in both attention and interpretation. Attention and interpretation biases were also positively correlated with one another. This indicates that a greater attention bias toward positive compared to negative material is linked to more positive compared to negative interpretations of ambiguous material.

Processing ability. Depressive symptom severity was negatively correlated with attention bias, but was not related to interpretation bias. Attention bias was again positively correlated with interpretation bias, showing that a higher ability to interpret ambiguous information in a positive manner is linked to a more positive emotional bias in attention.

Processing tendency and ability associations. Across-session correlations indicate that attention and interpretation biases during tendency and ability processing are relatively independent. Interpretation tendency and ability were only marginally related ($r=.26$, $p=.06$), and no significant correlations between attention biases emerged across sessions ($r=.08$, $p=.58$).

Bias-corrected bootstrapping analysis

Bias-corrected bootstrapping analyses with 5000 samples were conducted separately for tendency and ability processes. For tendency processes, we tested a mediation model with depressive symptom severity as the independent variable, interpretation bias as the dependent variable, and attention bias as the mediator. For ability processes, we tested an indirect effect model (cf. the non-significant relation between depressive symptom severity and interpretation bias) with depressive symptom severity as the independent variable, interpretation bias as the dependent variable, and attention bias as the intervening variable (Mathieu & Taylor, 2006).

Processing tendency. Bootstrapping analysis estimated the indirect effect of depressive symptom severity on interpretation bias via attention bias between 95%-CI: [-.0025, .0009] suggesting that the indirect effect is not significantly different from zero at $p<.05$ (indirect effect coefficient=-.0006, $SE=.0008$). The total effect, $c=-.019$ ($SE=.0024$), $t=-7.90$, $p<.001$, 95%-CI: [-.0236, -.0141], and the direct effect, $c'=-.0183$ ($SE=0.0025$), $t=-7.22$, $p<.001$, 95%-CI: [-.0233, -.0132] were significant. These results indicate that, for tendency processes, attention bias did not mediate the relation between depressive

symptom severity and interpretation bias. Instead, depressive symptom severity seems to have a direct effect on interpretation bias.

Processing ability. The indirect effect of depressive symptom severity on interpretation bias via attention bias was negative (indirect effect coefficient = $-.0007$, $SE = .0005$) and statistically different from zero ($p < .05$). The bias-corrected bootstrap confidence interval was entirely below zero, 95%-CI: $[-.0020, -.0001]$. This suggests that, for ability processes, attention bias acts an intervening variable in the relation between depressive symptom severity and interpretation ability. Both the total effect, $c = -.0014$ ($SE = .001$), $t = -1.36$, $p = .18$, 95%-CI: $[-.0035, .0007]$, and the direct effect, $c' = -.0007$ ($SE = 0.0011$), $t = -0.70$, $p = .49$, 95%-CI: $[-.0028, .0014]$, were not significant. The significant indirect effect and the non-significant total and direct effects provide support for the proposed indirect effect model.

Discussion

This study examined relations between depressive symptom severity, attention, and interpretation bias under tendency-driven and/or ability-driven processing conditions of new emotional material. The results showed (1) that depressive symptom severity was related to attention biases during tendency as well as ability processes, and (2) an indirect effect of depressive symptom severity on interpretation bias via attention bias as an intervening variable only for ability processes. These main findings are discussed in turn.

The significant correlations found between depressive symptom severity and attention biases during both tendency-driven and ability-driven processes suggest that depression-linked biases in attention may reflect influences of both schemas/prior learning and attentional control. This pattern of relations provides evidence for cognitive models of depression assuming that emotionally biased cognitive processes reflect processing tendencies driven by memory representations (Clark et al., 1999; Ingram, 1984; Williams et al., 1997)

as well as for cognitive views asserting that emotionally biased cognitive processes reflect regulatory deficits in attentional control (Joormann et al., 2007; Joormann, 2010). It also aligns with research indicating that depression-related attention biases can be guided by prior learning experiences of emotional material (Anderson et al., 2011; Fulcher et al., 2001; Hickey & van Zoest, 2013; Rohner, 2004; Schmidt et al., 2015) but also with research showing that depression-related attention biases are linked to deficient attentional control in the inhibition of negative information (De Lissnyder et al., 2010; Derakshan et al., 2009; Goeleven et al., 2006; Joormann, 2004). Interestingly, the indices of attention bias during tendency and ability processes were not correlated. This suggests that tendency-based biases and ability-driven deficits in emotional attention reflect relatively independent mechanisms that may influence emotional attention processing differently depending on the nature of the task.

This study also showed that attention bias acts as an intervening variable between depressive symptom severity and interpretation bias for ability processes, while this was not true for tendency processes. This finding suggests that attention operations linked to deficits in attentional control in depression may act as a relevant mechanism in the subsequent elaboration on or interpretation of emotional material. This finding provides further support for predictions by impaired cognitive control accounts of depression (Joormann et al., 2007; Joormann, 2010) and adds to prior research evidence testing the hypothesized indirect effect of depression-linked attention biases on the elaboration of new emotional information (Everaert et al., 2014, 2013). The absence of evidence for an indirect effect of depressive symptom severity on interpretation bias via attention bias for tendency processes does not rule out the role of tendency-based cognitive biases in depression. It only indicates that the current mediation model does not adequately represent the interplay

between depressive symptom severity, attention bias, and interpretation bias. This is further suggested by the significant correlations between depressive symptom severity levels and attention biases for tendency as well as ability processes. Future research may need to provide a more direct measure of memory bias or dysfunctional schemas to explicitly model this effect in relation to depressive symptoms and attention bias to capture their interplay during tendency processing.

The current observations have implications for the implementation of cognitive training methods to modify attention biases. Traditional attention bias modification procedures rely on experimentally established contingencies between to-be-detected targets and the location of positive or negative stimuli (MacLeod et al., 2002). However, these procedures have yielded mixed findings and overall small effect sizes in modifying attention bias and reducing symptoms of anxiety and depression (Beard et al., 2012; Hallion & Ruscio, 2011; Mogoșe et al., 2014). One explanation for these modest effect sizes may be that both processing tendencies as well as abilities need to be targeted where typically only one of these aspects is trained. It would be important to consider the plasticity or malleability of these different constituents of processing biases in depression. To effectively train or modify biases, future attention training procedures may need to target self-regulatory control in attention allocation. This could be achieved, for example, by increasing awareness of how attention is directed toward positive and negative stimuli when one processes emotional material (Bernstein & Zvielli, 2014) or by improving general cognitive control (Siegle et al., 2007). As a result of targeting self-regulatory control processes, this type of training procedures may also alter the emotional content of the interpretations drawn on emotionally ambiguous material.

The present study is not without limitations. First, the cross-sectional design precludes conclusions regarding the assumed influence of attention bias on interpretation for ability processes. As mentioned, direct proofs of cause-and-effect relations require experimental manipulation of attention bias (e.g., via cognitive control training) to examine training-related changes in interpretation bias. Second, the non-clinical nature of the recruited sample and the assessment of depressive symptom severity via a self-report measure limit the generalizability of our findings to depression. Further investigation of attention and interpretation biases during tendency and ability processes need to test whether similar dysfunctions cut across different samples representing the depression course (i.e., samples of non-depressed at-risk, clinically depressed, and formerly depressed individuals). Despite this limitation, the current findings remain of interest given that the magnitude of negative cognitive biases (e.g., in attention, interpretation) are a linear function of depressive symptom severity with cognitive shift from a positivity bias in healthy people to facilitated processing of negative information in clinically depressed people (Beck & Haigh, 2014; Clark et al., 1999).

In conclusion, this study aimed to advance insight into the attention – interpretation bias interplay in healthy and subclinically depressed individuals. Our findings suggest that depression-linked attention processing biases emerge both under processing tendency and ability conditions and, moreover, that an ability-dysfunction in attention may regulate how individuals elaborate on new emotional information.

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Chapter 5

Predictive Magnitude of Combined Cognitive Biases¹

Individuals with elevated depressive symptoms selectively attend to negative material (De Raedt & Koster, 2010), draw more negative interpretations on ambiguous information (Wisco, 2009), and recall disproportionately more negative memories (Gaddy & Ingram, 2014; Matt, Vazquez, & Campbell, 1992). Clarifying how emotional biases in these basic cognitive processes are involved in the course of depressive symptoms over extended time remains a major challenge for contemporary psychological scientists. Indeed, emotional biases in attention (Beevers & Carver, 2003), interpretation (Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002), and memory (Bellew & Hill, 1991) are individually predictive of future depressive symptoms, but how these related, yet distinctive, aspects of cognition interact to predict prospective changes in depressive symptom severity remains unknown. An integrative perspective to surpass individual bias effects seems

¹ Based on Everaert, J., & Koster, E.H.W. (in press) Emotionally biased cognitive processes: The weakest link predicts prospective changes in depressive symptoms. *Plos One*. doi: 10.1371/journal.pone.0124457.

necessary to advance knowledge on how biased cognitive processes contribute to depressive symptoms.

Integrative approaches to understand how cognitive factors work together in emotional disorders are relatively new (Abela & Sarin, 2002; Kraemer, Stice, Kazdin, Offord, & Kupfer, 2001). Two important approaches have been proposed to conceptualize the longitudinal impact of multiple depression-linked distortions in cognition (Abela & Hankin, 2008). First, the additive approach assumes that the severity of distorted cognitive factors has a cumulative effect, such that the risk to develop depressive symptoms increases with each additional factor. Applied to emotionally biased cognitive processes, the model predicts that individuals with more severe negative biases in multiple processes are at greater risk to develop depressive symptoms than individuals with fewer negatively biased processes. Second, a weakest link approach predicts that the course of depressive symptoms depends on the most pathogenic cognitive factor and not on the number of factors. The best marker of future increases in depressive symptoms would then be the cognitive process that is dominantly biased toward negative material. Many cognitive science approaches to depression hypothesize that distorted cognitive processes elevate depression risk under high levels of stress (Everaert, Koster, & Derakshan, 2012). This means that biased aspects of cognition and their combined effects predict changes in depressive symptoms through their interaction with perceived stress.

Research testing integrated models of distorted cognition as predictors of future depressive symptoms in adult samples is at the early stages. In research modeling effects of *content* aspects of cognition (e.g., questionnaire measures of dysfunctional attitudes and self-esteem) longitudinally, both the weakest link (Abela, Aydin, & Auerbach, 2006) and additive (Hankin, Abramson, Miller, & Haefffel, 2004; Reilly-Harrington, Alloy, Fresco, & Whitehouse, 1999) model received support. However, studies contrasting these approaches have

yielded mixed evidence for the model with the greatest predictive power. One study reported a high correlation ($r=.93$) between the weakest link and the additive model suggesting redundancy (Haefel, 2010). By contrast, another study observed greater power of the weakest link over the additive model in predicting prospective changes in depressive symptoms (Reilly, Ciesla, Felton, Weitlauf, & Anderson, 2012). Data regarding integrated models \times stress interactions are also mixed. While one study supports interactions between stress and integrative models (Haefel, 2010), the other study found the interaction did not significantly predict additional sources of variance (Reilly et al., 2012).

In research modeling longitudinal effects of *cognitive processes* (e.g., attention, memory), one study investigated whether prospective changes in depressive symptomatology and recovery status are predicted by multiple cognitive processes in a clinically depressed sample (Johnson, Joormann, & Gotlib, 2007). Neither attention nor memory bias was related to recovery at 9 months follow-up, and only memory for positive information at baseline was associated with lower symptom severity at follow-up. Although this study examined the predictive value of multiple biased cognitive processes individually, neither integrative models nor stress-interactions were tested. Unfortunately, this type of research on emotional biases in basic cognitive processes is currently absent. Clarifying the relation between biased cognitive processes and depressive symptoms seems instrumental in understanding both depression and biased aspects of cognition.

The present study aimed to advance understanding of emotionally biased cognitive processes as predictors of changes in depressive symptoms by adopting an integrative perspective. A first aim was to apply the additive and weakest link approaches to depression-linked biases in attention, interpretation, and memory to contrast the

models, testing their incremental utility. A second aim was to test whether integrative models interacted with perceived stress to predict the evolution in depressive symptoms.

Methods

A one-year follow-up was conducted building on a prior study (Everaert, Duyck, & Koster, 2014). In that study, we found that depression-linked biases in attentional selection and sustained attention regulate memory via different mechanisms: attentional selection was associated with emotional memory via its relation with interpretation, while sustained attention was directly related to memory bias. This study focuses on the predictive value of these biased cognitive processes for depression measures, one year later.

Participants

All 71 undergraduate students (62 women) who participated in the cross-sectional study were invited to contribute to the Time 2 assessment. Fifty-three participants (49 women) completed both time assessments (74.65%). Participants were native Dutch speakers between 17 and 33 years with normal or corrected-to-normal vision. All individuals provided written informed consent and received 5 euro. The study was approved by the institutional review board at Ghent University.

Time 1 Assessment

In a 70-minute session, participants started with a scrambled sentences test to measure interpretation bias. A computerized version of the test presented 60 emotional (e.g., “am winner born loser a I”) and 40 neutral (e.g., “the I theatre visit cinema often”) scrambled sentences in fixed random order.¹ There were 10 blocks, each comprising 6 emotional and 4 neutral sentences. Each sentence prompted participants to unscramble the item to form grammatically correct and meaningful statements using five of the six words (e.g., “I often visit the

theatre”). Unscrambled solutions were registered via coded report. To reduce social desirable responses, participants memorized a six digit number (i.e., a cognitive load) before each block and were prompted to recall the number after the block. While a scrambled sentence was on-screen, participants’ eye movements were recorded to assess attention biases toward emotional target words (e.g., “winner” and “loser” in “am winner born loser a I”). Target words were matched on word length, word class, and word frequency. Emotional scrambled sentences – which could be solved in either a positive or a negative manner – were of interest to infer emotional biases in interpretation and attention. The ratio of negative over the total emotional unscrambled sentences served as an index of interpretation bias. Attentional selection bias was indexed by the total number of fixations on negative target words divided by the total number of fixations on positive and negative target words of the scrambled sentences. Analogous calculations on the fixation durations on positive and negative target words provided an index of sustained attention bias.

After the task, participants received 5 minutes to recall the constructed unscrambled sentences. Memory bias was computed by dividing the number of negatively unscrambled sentences recalled accurately by the total number of unscrambled emotional sentences recalled correctly. Finally, participants filled out the Beck Depression Inventory – II (BDI-II) (Beck, Steer, & Brown, 1996; Van der Does, 2002) to assess depressive symptom severity. This questionnaire presents 21 statements to be rated on a scale from 0 to 3. The BDI-II has good reliability and validity in nonclinical and depressed samples (Beck et al., 1996; Van der Does, 2002). The internal consistency was $\alpha=.92$.

Time 2 Assessment

On average 368 days ($SD=25.66$; range: 347 – 523 days) later, participants were reassessed to determine depressive symptoms and

stress experienced prior to follow-up. Depressive symptoms were again measured by the BDI-II (internal consistency: $\alpha=.89$). To control for stress levels experienced prior to follow-up, the Perceived Stress Scale (PSS) (Cohen, Kamarck, & Mermelstein, 1983) assessed the degree to which participants appraised their life as stressful in the month prior to follow-up. The 10-item questionnaire presents disorder-unspecific items to provide a general estimation of how unpredictable, uncontrollable, and overloaded individuals have experienced their lives. Each item is rated on a scale from 0 (never) to 4 (very often). Research has supported the psychometric properties of the scale (Hewitt, Flett, & Mosher, 1992). The internal consistency was $\alpha=.88$ in this study.

Bias Composites

Bias indexes of attentional selection, sustained attention, interpretation, and memory were on the same metric, namely percentages reflecting preferential processing of negative over positive material (Everaert et al., 2014). An additive composite was computed by summing all four bias indexes per participant. A weakest link composite was computed by selecting the highest score of the bias indexes per participant. Each bias contributed to the weakest link composite. The dominant bias was in 26.42% of the participants attentional selection, in 26.42% sustained attention, in 18.87% interpretation, and in 28.30% memory bias.

Results

Descriptive Statistics and Attrition Analysis

A BDI-II mean of 13.56 ($SD=9.57$) was observed at Time 1 in the full sample. Attrition analyses indicated that participants who completed the Time 2 assessment ($n=53$) reported lower BDI-II scores at Time 1, $M=11.70$ ($SD=8.67$), than participants who did not complete the Time 2 assessment ($n=18$), $M=19.06$ ($SD=10.22$), $F(1,69)=8.83$,

$p < .01$. However, a broad range of BDI-II scores at Time 1 in the sample of completers was preserved: 34 individuals reported minimal, 6 mild, 11 moderate, and 2 severe depressive symptoms. Importantly, no differences emerged between completers and non-completers on the bias indexes (all F -s < 1). At Time 2, a mean BDI-II score of 10.51 ($SD=8.02$) and PSS score of 17.31 ($SD=6.92$; range: 6–34) was observed. The BDI-II scores at Time 2 demonstrated a broad range: 32 individuals reported minimal, 13 mild, 7 moderate, and 1 severe symptom levels.

Table 1. *Correlations between depressive symptom severity, stress, and bias composites.*

Variable	T1 BDI-II	T2 BDI-II	PSS	Weakest link
T1 BDI-II	—			
T2 BDI-II	.62 ^d	—		
PSS	.57 ^d	.78 ^d	—	
Weakest link	.33 ^c	.41 ^b	.11	—
Additive	.52 ^d	.46 ^d	.26 ^a	.75 ^d

Notes. ^a $p < .10$; ^b $p < .05$; ^c $p < .01$; ^d $p < .001$; BDI-II=Beck Depression Inventory – II; PSS=Perceived Stress Scale (measured at time 2); Weak to moderate correlations were observed between individual cognitive biases at Time 1. Sustained attention correlated with selective orienting, $r=.54$, $p < .001$, and memory, $r=.39$, $p < .01$, but not with interpretation, $r=.18$, $p=.20$. Selective orienting correlated with interpretation, $r=.34$, $p < .05$, but not with memory bias, $r=.21$, $p=.13$. Interpretation correlated with memory bias, $r=.52$, $p < .001$. None of the four cognitive biases were redundant and the strength of the observed correlations is similar to correlations reported between cognitive content variables (Reilly et al., 2012).

Correlational Analysis

The additive and weakest link composites were correlated and related to depressive symptom severity levels at both time assessments. Experienced stress was not related to the either composite score. Table 1 presents correlations between depressive symptoms, perceived stress, and cognitive bias composites.

Prediction of Depressive Symptoms

To test the predictive value of each integrative model and its interaction with perceived stress, three-step hierarchical regression analyses were conducted per bias composite. In a first step, BDI-II scores at time 1 (T1 BDI-II) and PSS scores were entered to create a residual change score for BDI-II scores at time 2 (T2 BDI-II) and to control for proximal stress levels. The composite was added in a second step and its interaction with perceived stress in a third step. All predictors were z -transformed. Note that, to obtain composite-by-stress interaction indexes, the lowest value of the standardized scores was added to the variable before multiplying both variables (Abela & Sarin, 2002). For each analysis, collinearity statistics were within acceptable limits indicating low levels of multicollinearity ($VIF < 1.79$; $Tolerance > .55$). Table 2 presents coefficients and statistics per model.

Tests of the *additive model* revealed that T1 BDI-II and PSS accounted for 65.4% of the variance in step 1, $F(2, 49) = 46.22, p < .001$. The additive composite in step 2 explained an additional 3.0% of the variance, $\Delta F(1, 48) = 4.54, p < .05$, and its interaction with stress in step 3 did not significantly add to the model, $\Delta R^2 = 1.0\%$, $\Delta F(1, 47) = 1.59, p = .21$. The variables included in step 2 accounted for 68.4% of the variance in depressive symptoms at Time 2, with PSS ($\beta = .64, p < .001$), the additive composite ($\beta = .20, p < .05$), but not T1 BDI-II ($\beta = .16, p = .15$) as significant predictors of T2 BDI-II.

Analysis of the *weakest link model* showed that adding T1 BDI-II and PSS in step 1 contributed significantly to the regression model, $F(2, 49) = 46.22, p < .001, R^2 = 65.4\%$. Introducing the weakest link composite in step 2 explained an additional 8.8%, $\Delta F(1, 48) = 16.46, p < .001$. Adding the weakest link \times stress interaction in step 3 explained no additional variance, $\Delta R^2 = 0\%$, $\Delta F < 1, p = .98$. Of the variables included in step 2, not T1 BDI-II ($\beta = .15, p = .11$), but PSS ($\beta = .66, p < .001$) and the weakest link composite ($\beta = .31, p < .001$) predicted T2 BDI-II. Together,

these variables accounted for 74.2% of the variation in depressive symptomatology at Time 2.

Table 2. Hierarchical regression models testing integrative models.

Predictor	Additive model				Weakest link model				
	<i>b</i>	<i>SE_b</i>	β	<i>t</i>	<i>b</i>	<i>SE_b</i>	β	<i>t</i>	
Step 1	Constant	10.83	0.69		15.61 ^d	10.83	0.69		15.61 ^d
	T1 BDI-II	2.25	0.90	.26	2.50 ^b	2.25	0.90	.26	2.50 ^b
	PSS	5.11	0.82	.64	6.24 ^d	5.11	0.82	.64	6.24 ^d
Step 2	Constant	7.87	1.54		5.12 ^d	8.00	0.92		8.67 ^d
	T1 BDI-II	1.39	0.96	.16	1.45	1.34	0.82	.15	1.64
	PSS	5.14	0.79	.64	6.51 ^d	5.30	0.72	.66	7.41 ^d
	Composite	1.67	0.78	.20	2.13 ^b	2.74	0.68	.31	4.06 ^d
Step 3	Constant	7.66	1.54		4.98 ^d	8.00	0.93		8.57 ^d
	T1 BDI-II	1.31	0.95	.15	1.37	1.34	0.82	.15	1.62
	PSS	3.87	1.28	.48	3.02 ^c	5.28	0.96	.66	5.49 ^d
	Composite	0.52	1.20	.06	0.44	2.72	1.15	.31	2.36 ^b
	Composite × PSS	0.71	0.56	.26	1.26	0.02	0.55	.00	0.03

Notes. ^a*p*<.10; ^b*p*≤.05; ^c*p*<.01; ^d*p*<.001; BDI-II=Beck Depression Inventory – II; PSS=Perceived Stress Scale.

Incremental Utility

Prior analyses revealed that both integrative models predict the prospective change in depressive symptoms, with the weakest link model explaining a larger proportion of variance (8.8%) compared to the additive model (3.0%). To test the incremental utility of the weakest link model, a hierarchical regression analysis was conducted with T1 BDI-II and PSS added in step 1, and the additive and weakest link composites entered in step 2 and 3, respectively. Collinearity statistics were within acceptable limits (VIF<2.7, Tolerance>.44). Results showed that adding the weakest link composite in step 3 significantly added to the model including T1 BDI-II, PSS, and the additive composite, $\Delta R^2=6.2\%$, $\Delta F(1, 47)=11.39$, *p*<.01. Of the variables in step 3, PSS ($\beta=.66$, *p*<.001) and the weakest link composite ($\beta=.37$, *p*<.01),

but neither T1 BDI-II ($\beta=.18, p=.08$) nor the additive composite ($\beta=-.09, p=.44$) predicted T2 BDI-II.

Potential Confounds

Partial correlations controlling for T1 BDI-II showed that neither the number of days between Time 1 and Time 2 assessment, $r_{\text{partial}}=.10, p=.50$, nor gender, $r_{\text{partial}}=.18, p=.20$, nor age, $r_{\text{partial}}=-.02, p=.89$, were related to T2 BDI-II. The above findings are thus not confounded by these variables.

Discussion

The present study is to the best of our knowledge the first to examine emotionally biased cognitive processes in interaction with perceived stress as predictors of prospective changes in depressive symptomatology by adopting an integrative perspective. It was found that the weakest link model had incremental utility over the additive model in predicting the change in depressive symptoms, although both models significantly predicted the change in depressive symptoms over time. In addition to the large proportion of variance accounted by depressive symptoms at Time 1 and perceived stress levels (65.4%), the weakest link composite (8.8%) explained more than two times the variability in the evolution of symptomatology at Time 2 than the additive composite (3.2%). This suggests that the best cognitive marker of prospective fluctuations in depressive symptoms does not depend on the number of emotionally biased cognitive processes, but instead on the severity of emotional bias (toward negative material) in the most affected cognitive process. Notwithstanding the variance explained by perceived stress, stress did not interact with integrative models to predict changes in depressive symptoms. In line with prior studies (Johnson et al., 2007; Rude et al., 2002), this finding suggests that cognitive biases can operate regardless of experienced stress, which contradicts predictions by several cognitive science approaches to

depression (Everaert et al., 2012). However, cautious conclusions are warranted given that only few prospective studies have examined cognitive process \times stress interactions and these have yielded inconsistent findings (Haefel, 2010; Reilly et al., 2012). Note that the measure of stress in this study may have lacked sensitivity to detect idiographic changes. Despite the considerable variability in perceived stress scores to demonstrate interaction-effects, the baseline to rate stress may have differed across participants providing an inaccurate estimation of increases in stress prior to Time 2 assessment.

The present findings make two important contributions. First, they extend prior research in that this study applies integrative approaches to model longitudinal relations between multiple cognitive factors and depressive symptoms to the study of emotional biases in basic cognitive processes, which have generally been investigated in isolation and without stress-interactions (Johnson et al., 2007). The present observations add to research on cognitive content factors supporting the incremental validity of the weakest link over the additive approach (Reilly et al., 2012), and diverge from research suggesting redundancy between the integrative models tested (Haefel, 2010). In line with the combined cognitive biases hypothesis stating that “*combinations of biases have a greater impact on disorders than if individual cognitive processes acted in isolation*” (Hirsch, Clark, & Mathews, 2006), the current data suggests that multiple *interactive* cognitive biases need to be considered to identify –within individuals– the bias with the greatest impact. Even though the best predictive potential may reside in one particular cognitive bias at one point in time, this biased cognitive process can still exert a strong influence other processing biases later on (Everaert et al., 2014; Everaert, Tierens, Uzieblo, & Koster, 2013; Everaert & Koster, 2015).

Second, the findings have practical implications for cognitive training methods that manipulate emotional biases in cognitive

processes and have been implemented as tools to prevent future depressive symptoms (Browning, Holmes, Charles, Cowen, & Harmer, 2012). If an individual's weakest link is the best maker of future increases in depressive symptoms, cognitive training may be more effectively implemented after mapping an individual's cognitive profile with various distorted aspects of cognition such that training can be tailored toward the cognitive process that is most affected in order to prevent future depressive symptoms. Note, that this study is the first to test the predictive value of integrative approaches to cognitive biases. Replication in clinical samples is required before such a strategy could be employed in clinical settings.

Some limitations of this study should be acknowledged. A first limitation is that we did not examine whether the predictive power of multiple cognitive processes differs in first-onset versus recurrent depression. Future work will need to take into account the number of past depressive episodes to clarify differential predictive effects of integrative approaches. Another limitation is that we conducted the study in a sample with subclinical symptoms of depression and we did not take a diagnostic assessment of clinical depression. Instead, we investigated the predictive value of multiple cognitive processes in relation to prospective changes in self-reported symptoms. However, the present results remain of interest given that individuals with subclinical symptom levels experience significant symptomatic suffering, impaired role functioning, are at greater risk to develop clinical depression (Ingram & Siegle, 2009), and the cognitive biases under study here may contribute to this pathogenesis. Future research may extend the current work by examining the potency of integrated models to predict clinical outcomes such as recovery status in remitted and clinical samples. A final limitation concerns the scale to evaluate perceived stress which may have not been sufficiently sensible to detect the stressful events experienced during the follow-up period. The scale

measured perceived stress one month prior to follow-up to statistically control for proximal stress levels to examine the predictive value of the proposed integrative approaches. However, interview-based assessments that monitor the different stressful situations experienced during the full follow-up period may be preferred to test predictions by cognitive models of depression.

This study investigated integrative effects of multiple emotional biases in basic cognitive processes as predictors of the future evolution of depressive symptoms. The weakest link model integrating attention, interpretation, and memory biases had incremental utility over the additive model, but did not interact with stress to predict the change in depressive symptomatology. This highlights the importance of considering multiple biased cognitive processes in evaluating effects of cognitive factors on the longitudinal course of depressive symptoms.

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General Discussion

Research on cognitive risk factors to depression has long recognized the relevance of emotional biases in basic cognitive processes such as attention, interpretation, and memory. A recent surge of studies examining the interactions between emotionally biased cognitive processes is augmenting our understanding of each individual bias as well as emotionally disordered cognitive functioning as a whole. It is now known that attention, interpretation, and memory biases are not independent, isolated mechanisms. Instead, cognitive biases seem to operate constantly and with mutual influences to have a combined impact on the course of depressive symptoms. In this chapter, we discuss the key findings and main conclusions from the research presented in this doctoral dissertation. We first summarize the most important results to describe their implications for cognitive theory and research, as well as possible clinical applications in the next section. Then, we consider a number of general limitations to the studies presented. Finally, we outline several directions and challenges for future study to deepen our understanding of the interplay between emotionally biased cognitive processes in depression.

On The Knowledge Increment

The general objective of this PhD research was to advance understanding of interactions among emotional biases in attention, interpretation, and memory. In samples of healthy and subclinically

depressed individuals, we aimed to address several lingering questions: (1) How does emotional attention regulate what is remembered?; (2) Does emotional long-term memory guide attention?; (2) What is the role of interpretation in the attention – memory bias interaction?; (4) Do multiple cognitive biases combine to predict future depressive symptoms?. Related to the three core areas that originate from the combined cognitive biases hypothesis (see chapter 1), we set out a series of cross-sectional studies to investigate linkages between cognitive biases (association questions), cognitive training studies to test the assumed direction of effects (causal questions), and a longitudinal study to examine the predictive value of multiple cognitive biases (predictive magnitude questions). The following summary of our main findings is organized into these three core areas.

Association Questions

The first empirical efforts focused on the role of emotional biases in attention and interpretation during encoding and retrieval in explaining congruent biases in memory (chapter 2). Experiment 1 aimed at testing specific functional relations among emotional biases in attentional selection, sustained attention, and interpretation during incidental encoding of emotional material and how their interplay is reflected in memory. Healthy and subclinically depressed individuals completed a computerized version of the scrambled sentences test (to measure interpretation bias) while their eye movements were recorded (to measure *overt* attention biases). This task was followed by an incidental free recall test of previously constructed interpretations (to measure memory bias). The observations indicated that an emotional bias in memory can be explained by sustained attention bias and interpretative choices, with the latter being regulated by a bias in attentional selection. Emotional biases in distinct attentional mechanisms (attentional selection, sustained attention) during

encoding seem to regulate emotional memory in a direct and indirect manner.

The findings from experiment 2 added further support for an indirect effect of attention bias on emotional memory via interpretation bias. In this study, healthy and subclinically depressed individuals completed a spatial cueing task (to measure *covert* attention bias), followed by a scrambled sentences test (to measure interpretation bias), and an incidental free recall task (to measure memory bias). The results revealed that an emotional bias in attention is related to a congruent bias in interpretative choices which are in turn reflected in memory.

Emotional biases in attention and interpretation at encoding predict emotional biases in memory for encountered emotional material. However, still little is known about the role of such attentional biases during the process of emotional memory retrieval. Experiment 3 was designed to investigate how emotional biases in memory are related to attentional mechanisms during retrieval. Participants encoded emotionally positive and negative meanings derived from ambiguous information (i.e., the items from a scrambled sentences test), and then searched their memory for encoded meanings in response to a set of retrieval cues (i.e., the disambiguating words from a scrambled sentence). The remember/know/new procedure was used to classify memories as recollection- or familiarity-based, and gaze behavior was monitored throughout the task to measure attentional allocation. The data showed that a bias in sustained attention during recollection-based and not during familiarity-based retrieval predicted subsequent memory bias toward positive versus negative material after controlling for encoding. Thus, during emotional memory retrieval, attention affects controlled forms of retrieval (i.e., recollection) and does not modulate relatively automatic, familiarity-based retrieval.

In a subsequent series of experiments, we sought to model how emotional memory associations could in turn guide attention (chapter

3). In an initial encoding phase, distinct colors were consistently paired with faces depicting either happy, neutral, or angry expressions while participants performed a cover task. The colors were presented as task-irrelevant stimuli in a subsequent visual search (experiment 1) or cueing (experiment 2) task. Both studies revealed that emotional memory associations contribute to attention such that individuals show greater attentional guidance by positive associations and attentional avoidance from negative memory associations. However, no double biases were found in a single study suggesting a dissociation between memory-guided attention effects of positive versus negative associations in memory. Memory-based attention biases to stimuli with positive associations were related to memory accuracy while this was not true for negative memory associations. This suggests that different memory systems may contribute to attention. Regarding the temporal profile, the negative memory associations modulated attentional capture at short stimulus exposure durations without altering attentional disengagement. Taken together, these experiments provide some evidence that based on prior affective learning, attention can be biased toward stimuli with positive associations and away from stimuli with negative memory associations.

In conclusion, the cross-sectional research shows that attention and memory biases are interdependent processes with interactions at several processing stages. Emotional biases in distinct attentional operations regulate the emotional content of memories at encoding and retrieval. Depending on the attentional mechanisms (attentional selection, sustained attention), the processing stage (encoding, retrieval), and the retrieval process (controlled, automatic), attention may regulate what is remembered. Emotional memory may in turn control attention such that emotional memory associations guide attention toward or away from stimuli with positive or negative associations. The memory-guided attention effect may depend on the

attentional mechanism (attentional capture, attentional disengagement), stimulus exposure duration, and the emotional valence of the associations in memory.

Causal Questions

The temporal sequence of the experimental tasks tapping into different cognitive biases and the similar stimulus materials presented across tasks are design features that optimize conditions to test the effect of one cognitive bias on another process. Consequently, we can have some confidence in the modeled direction of effects in these studies. Direct proof of causality, however, still requires experimental manipulation of one bias to investigate effects on other processes.

The goal of first three experiments presented in chapter 4 was to examine the influence of emotional biases in attention on other cognitive processes using single-session attention bias modification with a training variant of the dot-probe task. In experiment 1, participants received training either toward or away from negative images or no-training, and transfer to an affective task-switching task was examined. In experiments 2 and 3, participants were trained to orient attention toward either positive or negative words or facial expressions, and transfer to an interpretation bias task was examined. In all experiments, the dot-probe training procedure did not effectively modify biases in attention allocation at the training condition level and produced large variability in individual attention bias acquisition within and across conditions. Individual differences in pre-training attention bias and attention bias acquisition were also not related to performance on the affective task-switching task or the interpretation tests.

The findings from the three experiments provided no evidence for single-session dot-probe attention bias modification procedures to effectively manipulate attention bias toward negative, away from negative, or toward positive stimuli at the training condition level. Also

at the individual differences level of analysis no evidence was found for transfer of attention training. As a result of the lack of effectiveness of the attention training procedure, we were not able to test the hypothesized causal influence of attention bias on interpretation nor on affective task-switching ability.

To gain a better understanding of the nature of attention and interpretation biases that are typically targeted by cognitive bias modification procedures, we examined how processing tendency (i.e., driven by schemas or prior learning) or an ability-related process (i.e., dependent on attentional control) are involved in these cognitive biases. In experiment 4, participants completed two scrambled sentences tests in separate experimental sessions. Participants received standard task instructions in the first session, while in the second session they were required to unscramble the sentences into positive statements. These different versions respectively index tendency and ability processes involved in ambiguity resolution. Eye-tracking was used to assess attention bias during each task variant. The results showed that depressive symptom severity was correlated with attention bias under both tendency and ability conditions. Analyses showed that attention bias (i.e., the fixation time spent on positive versus negative words) acted as an intervening variable in the relation between depressive symptoms and interpretation bias only during ability processes. These findings suggest that depression-linked biases in attention reflect both processing tendencies and ability-related processes in attentional control, with attentional control as a relevant mechanism in the subsequent interpretation of emotional material. This pattern of findings imply that cognitive control training rather than cognitive bias modification methods are more suitable to investigate the influence of attentional biases on other cognitive processes.

Taken together, the attempts to modify emotional attention biases via traditional experimental procedures were not successful at

inducing emotional biases in attention that transferred to interpretation or affective task-switching ability. As a result, we were not able to substantiate the hypothesized causal directions proposed by the cross-sectional research findings. One explanation for the limited effects of the attention training resides in the nature of the targeted cognitive bias itself. Depression-related biases in attention while making meaning may reflect processing ability deficits which are less susceptible to traditional attention bias modification procedures.

Predictive Magnitude Questions

The research presented in the chapters 2, 3, and 4, examined the interplay among multiple depression-linked cognitive biases within a proximal timeframe, leaving unanswered how emotionally biased cognitive processes in combination impact the longitudinal course of depressive symptoms. To address this open issue, the prospective study presented in chapter 5 tested the predictive magnitude of two integrative approaches that model relations between multiple biased cognitive processes in interaction with perceived stress. The combined impact of multiple cognitive biases was operationalized using additive ('cognitive processes have a cumulative effect') and weakest link ('the dominant pathogenic process is important') models. At Time 1, participants completed measures of depressive symptom severity and emotional biases in attention, interpretation, and memory. At Time 2, one year later, participants filled out questionnaires to assess depressive symptom severity levels and stress experienced shortly prior to follow-up.

The data revealed that the weakest link model had incremental validity over the additive model in predicting prospective changes in depressive symptoms, even though both models explained a significant proportion of variance in the change in depression levels. Remarkably, none of the integrative models interacted with perceived stress to predict changes in depressive symptomatology. The observations

indicate that the best cognitive marker of the evolution in depressive symptoms is the cognitive process that is dominantly biased toward negative material, which could operate independent from experienced stress. This highlights the importance of considering idiographic cognitive profiles with multiple cognitive processes for understanding effects of cognitive biases in depression.

Conclusion

Depression-linked biases in attention, interpretation, and memory are highly interactive cognitive biases. Emotionally biased attentional mechanisms can regulate the emotional content of remembered interpretations via modulation of encoding and retrieval processes. Emotional memory associations can in turn guide attention allocation. Attention biases may also be controlled by deficient cognitive control processes. Via their interactions, cognitive biases have a combined effect on the longitudinal course of depressive symptoms, with the weakest link as the best cognitive marker. All together, these observations indicate that the impact of one cognitive bias cannot be fully understood except in the context of other biases. The knowledge gained here is important for characterizing the cognitive foundations of depression and has important theoretical and clinical implications.

Implications For Theory, Research and Practice

Cognitive Models of Depression

Our findings provide evidence for several predictions by cognitive science approaches to depression. In line with theoretical hypotheses, attentional bias regulates interpretation of emotionally ambiguous material (Joormann, Yoon, & Zetsche, 2007; Williams, Watts, MacLeod, & Mathews, 1988) and enhanced elaboration results in improved memory for the created interpretations (Ingram, 1984; Joormann et al., 2007; Williams et al., 1988; Williams, Watts, MacLeod, & Mathews, 1997). The products of the elaboration process

may serve as mnemonic cues that help to retrieve these emotional meanings from memory at later points in time (Williams et al., 1997). In line with the notion that negative memory schemas bias information processing (Clark, Beck, & Alford, 1999), we found that emotional associations in memory can guide attention toward emotionally congruent material. Moreover, we also found support for the role of attentional control difficulties during elaboration on emotional material (Hertel, 1997; Joormann et al., 2007). Attentional control may mediate the relation between depressive symptoms and interpretation. Both memory schemas and cognitive control difficulties may modulate attentional mechanisms (attentional capture, sustained attention) involved in biased elaboration on negative material. As predicted by some cognitive models (Ingram, 1984), emotionally biased cognitive processes combine in the prediction of future depressive symptoms.

Different theoretical perspectives with their shared and unique predictions seem to provide complementary views on the processes involved in the interplay between emotionally biased cognitive processes (e.g., impaired cognitive control accounts vs. enhanced elaboration accounts; see also chapter 1). Although several theoretical hypotheses have not been confirmed (see chapter 1), our observations indicate that each of the cognitive models describes some aspects of the interactions that may occur between cognitive biases and may hold some truth. When putting theoretical predictions derived from different cognitive models to the empirical test, we should not approach these models as competing perspectives but as complementary explanations for the complex nature of interacting cognitive biases. Investigators may need to work toward a comprehensive theoretical framework integrating ideas from several cognitive models of depression to grasp the interactions that exist between cognitive biases.

Despite frequent theoretical attempts to understand the cognitive mechanisms underlying depression, many cognitive accounts

of depression do not integrate insights from basic cognitive and clinical science in an attempt to understand the interactions between emotionally biased cognitive processes. An update of depression models' predictions with regard to their hypotheses relevant to the interplay between attention, interpretation, and memory seems necessary. It is remarkable that established as well as recently developed models (1) do typically not distinguish between distinct components of cognitive processes and (2) are underspecified with regard to possible interactions that may occur between these processes, and (3) how interactive cognitive biases exert a long-term impact on depression. These issues are discussed in turn.

It is well-known that cognitive processes such as attention and memory are not unitary mechanisms. Attention involves selection and maintenance (also referred to as modulation) operations (Chun, Golomb, & Turk-Browne, 2011; Yiend, 2010) and memory comprises explicit and implicit systems (Hutchinson & Turk-Browne, 2012). Some theorists have argued that the process of interpretation also involves different mechanisms, including automatic and effortful activation as well as selection mechanisms (Wisco, 2009). Although many empirical studies on cognitive biases consider distinct components of the cognitive processes under investigation (Jermann, Van Der Linden, Laurençon, & Schmitt, 2009; Yiend, 2010), this complexity is rarely reflected in theoretical perspectives on depression-related processing biases. For example, cognitive models do frequently not consider emotional biases in attentional selection and sustained attention when explaining difficulties in withdrawing or disengaging attention from processing of negative material, which is regarded as characteristic for depressed people. Distinguishing between different components of cognitive processes seems important given the differential relations between specific processes. For example, attentional selection and sustained attention biases at encoding and retrieval have different

relations with later remembering of emotional material (e.g., controlled versus automatic retrieval). Also emotional memory may have in turn an impact only on specific attentional mechanisms such as attentional capture. Via such differential relations, distinct components or systems of attention and memory may play a different role in the maintenance of depressive symptoms.

In addition to the low level of specificity in theoretical predictions regarding components of cognitive biases, many cognitive models also lack specificity in their predictions regarding the interactions that could occur between cognitive biases. The role of attention bias in explaining memory bias extends beyond its influence on the encoding of new, external information or on the elaboration of activated memories. The interplay between attention and long-term memory seems more complex than is currently assumed by many cognitive views on depression. The presented research suggests that biases in different attention operations can modulate emotional memory bias via their role in incidental encoding of new experiences as well as controlled, but not automatic, memory search to retrieve an emotional experience. The emotional memory content may have in turn the ability to guide attention such that emotionally congruent material captures attention. Attention and memory biases are thus overlapping processes during stimulus-based and memory-based processing of emotional material. In their interactions, cognitive biases may exert a combined influence on the course of depressive symptoms. Based on current models, however, it is difficult to point down a theoretical explanation for the finding that a weakest link represented the best marker of future increases in depressive symptom severity. Here, an integration of cognitive and affective processes, such as emotion regulation strategies, may help to explain this finding (see ‘emotion regulation strategies’).

Future updates of the contemporary theoretical perspectives on processing abnormalities in depression need to incorporate a more fine-grained set of predictions regarding the interplay between cognitive biases. This seems essential given that a lack of specific predictions limits theory-based generation of falsifiable hypotheses and may impede future efforts to grasp depressive cognitive functioning as well as therapeutic strategies inspired by these models. Research should not be restricted to predictions set out by established or recently formulated theoretical models, but it should strive to extend contemporary views beyond their current boundaries.

Emotion Regulation Strategies

Insight into the interactions between biased cognitive processes is not only relevant to our theoretical understanding of the cognitive foundations of depression, it also provides a framework to understand healthy and disordered emotional functioning. Recent cognitive models of depression have hypothesized that individual differences in cognitive biases affect the use and effectiveness of regulating strategies to repair or reverse a mood state, maintaining cardinal symptoms of depression such as persistent negative affect (Joormann & D'Avanzato, 2010; Joormann, 2010; Koster, De Lissnyder, Derakshan, & De Raedt, 2011).

Considerable research has shown that depression is characterized by difficulties in emotion regulation. Depressed individuals tend to ruminate more in response to sad mood or stress, reappraise a situation's meaning less frequently relative to healthy people, and have difficulties using mood-incongruent recall to repair negative mood (Joormann & Vanderlind, 2014). The findings of the presented doctoral research may cast light on the cognitive processes underlying difficulties in emotion regulation and may explain why depressed people initiate a malicious cycle of negative thinking and increasing negative mood.

When people are exposed to ambiguous, stressful situations (e.g., a job interview), individuals with higher depressive symptom levels tend to orient attention more frequently toward negative than positive stimuli (e.g., a frowning versus a smiling interviewer) and dwell longer on this negative material. Difficulties in attentional control to disengage from processing negative material may prevent reorienting of attention to positive or neutral stimuli as an anticipatory emotion regulation strategy (e.g., focusing on the other assessors) and endorse negative interpretations of a particular situation (e.g., “I am making a bad impression”, “they think I am not capable for the job”). Initial interpretations could be maintained by sustained attention toward negative material and a rigid interpretation tendency, hindering reappraisal of the situation that could lead to more balanced interpretations (e.g., “it was not that bad at all”). This process may consolidate dysfunctional memory representations (e.g., “I am worthless”) and activate mood-congruent memories (e.g., broken relationship) that may fuel negative thoughts (i.e., rumination). Biased encoding of negative material sets the stage for mood-congruent memory biases and may jeopardize the use of mood-incongruent recall to repair negative mood in the future.

Negative cues in the particular situation may be used to guide memory search in an attempt to retrieve prior experiences, which is likely to result in retrieval of mood-congruent memories that could worsen the distressed mood (e.g., “last time I also did a bad job on the interview: I’m a loser”). The negative experiences that are retrieved may not only fuel negative thinking, but may also guide attention toward other negative cues, reinforcing initial negative interpretations and preventing reappraisal. Furthermore, the flexibility in using mood-congruent and incongruent memories to regulate mood may decrease over time because selectively retrieving a memory increases the likelihood of later forgetting a un-retrieved memory (e.g., “last time I

did well on an interview: I'm a winner") that shares associative links (Anderson et al., 2004). This is because retrieval strengthens memory associations and weakens associations for not-retrieved memories, which could result in relatively stable tendencies to retrieve memories from a particular emotional category.

Through the constant interaction between cognitive biases, depressed individuals may become locked into a vicious circle of negative thinking with an inability to regulate negative thoughts and emotions. Particular emotion regulation strategies preferred by an individual (e.g., unsuccessful reappraisal, mood-incongruent retrieval) may become habitual tendencies which could in turn aggravate negative biases in basic cognitive processes. This reciprocal process may differentially impair certain negative cognitive biases within individuals, such that one particular cognitive bias becomes an individual's weakest link that best predicts future symptoms of depression.

It is clear that cognitive biases and their interactions are instrumental in explaining difficulties in the selection and effectiveness of emotion regulation strategies and the consequences for experienced mood states. To date, however, studies have only demonstrated that healthy people differ from depressed people in their cognitive biases and emotion regulation. Very few studies have explicitly linked depression-related cognitive biases, emotional experience and regulation within proximal or distal timeframes. Integrating cognitive and affective processes underlying depression presents an important goal for future research to improve our understanding of hallmark symptoms of depression.

Cognitive Training

Insights gained from basic research examining interactions between cognitive biases and their combined impact on depressive symptoms has implications for the development and implementation of cognitive training methods. The presented research findings may

inform strategies to more effectively target cognitive vulnerability factors and to prevent future depressive symptoms.

Reducing cognitive vulnerability

Cognitive training could take advantage of the role of attentional mechanisms in regulating memory encoding and retrieval. The cross-sectional research findings suggest that modifying attention bias may alter later processing of the emotional material (e.g., interpretation, memory bias) and could modulate controlled retrieval of emotional memories. If a negative bias occurring at the early stages of processing new material could be effectively reduced, this may normalize later information processing and may reduce vulnerability to depression in that dysfunctional beliefs (memory representations) about the self and others are modified into more adaptive views.

While it seems logical to target emotional biases at the attention level to alter maladaptive cognitions, current meta-analytic evidence has yielded only modest effect sizes for current attention training procedures in terms of clinical outcomes (Hallion & Ruscio, 2011; Mogoșe, David, & Koster, 2014) and also our experiments have indicated that training biases in attention transfer neither to interpretation nor to affective task-switching ability. The latter finding suggests that even if trained individuals were able to reallocate attention from negative to positive aspects of an ambiguous situation (e.g., a smiling interviewer during a job interview), they do not necessarily interpret the incoming material in a positive manner (e.g., “This does not apply to me, I don’t believe I’m making a good impression”). A lack of transfer of training to critical cognitive processes obviously limits the application of attention bias modification as a tool to reduce cognitive vulnerability to depression.

One possible factor that could (partly) explain the lack of training effects and transfer to interpretation may reside in emotional memory. The support we found for memory-based biases in attention

allocation suggests that emotional memory contents may hinder effective implementation of attention training by interfering with training effects on attention and its transfer to interpretation. That is, while cognitive training may direct one's attention toward positive and away from negative stimuli, memory may guide attention away from stimuli with positive associations in depressed individuals. Moreover, it is likely that memory serves as a source from which past experiences are retrieved and used to interpret an ambiguous situation, in that way interfering with potential transfer of a positive attention bias to interpretation.

To obtain clinically significant and relatively stable effects of training on attention, training procedures may not only have to target attention bias such that individuals can more swiftly reallocate attention from negative to positive material in contexts relevant to an individual's concerns, but training procedures may also have to boost transfer of training to memory such that it results in new or modified memory representations. This is to reduce the memory-based influences on attention and potentially also on interpretation which could compromise the delivery of attention training. Indeed, there is some evidence for effects of single-session dot probe attention training on memory in individuals with higher depression levels (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013), but further research that aims at illuminating learning and memory process involved in attention training to boost such transfer of training is required (Abend, Pine, Fox, & Bar-Haim, 2014). Attention training studies may consider proof of transfer of training to cognitive processes such as interpretation and memory as a criterion to assess the effectiveness of a training procedure.

A way to enhance effects of attention bias training, and potentially transfer to memory, can be derived from our observations suggesting that emotional biases in attention when elaborating on

emotional material may reflect processing ability deficits. In addition to memory-based effects, ability-based deficits in attention allocation may be a factor accounting for the large inter-individual variability in the effectiveness of attention bias modification. Traditional attention bias modification techniques may not be optimal for individuals who have pronounced deficits in cognitive control while processing negative material. This group of individuals may take more advantage of cognitive control training procedures that directly target ability dysfunctions (Calkins, McMorran, Siegle, & Otto, 2014; Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013; Siegle, Ghinassi, & Thase, 2007). Therefore, identification of the factor(s) that drive attentional biases within individuals may reveal the most effective training procedure to target attention bias in order to reduce vulnerability to depression. This could be either attention bias modification or cognitive control training or a combination of these training methods.

Preventing depressive symptoms

Cognitive training techniques could be used as an efficient tool to prevent future depressive symptoms if such procedures target the best marker for future depressive symptoms (Browning, Holmes, Charles, Cowen, & Harmer, 2012). Our findings suggest that such practices may benefit from pre-training assessments of an individual's cognitive profile to identify the weakest link, instead of delivering cognitive training to whole groups without prior assessment. Multiple cognitive biases may need to be considered within individuals to identify and target the cognitive bias with the greatest predictive magnitude of the depression course. This implies that the targeted cognitive biases are not necessarily attentional processes as proposed in the previous paragraph. However, targeting an individual's weakest link (e.g., interpretation bias) may also influence other biases (e.g., memory) which could have in turn an impact attentional biases.

Although speculative, a combined cognitive training approach targeting early processing biases (e.g., attention) and an individual's weakest link may hold most promise to reduce cognitive vulnerability and to prevent future depressive symptoms.

Limitations

There are a number of general limitations to the research in this doctoral dissertation. First, the studies were conducted in nonclinical samples of undergraduate students which may limit the generalizability of the findings to clinical depression. It is frequently assumed that cognitive biases observed in such convenient samples of individuals with subclinical symptom levels differ from clinical samples in terms of degree rather than kind (Beck & Haigh, 2014; Yiend, 2010). However, few studies have directly compared emotional biases in cognition in subclinically versus clinically depressed samples to identify possible differences and/or similarities. One study that compared the strength of attention biases in individuals with minimal, mild, and moderate to severe depressive symptoms found that maintained attention toward negative information was associated with moderate to severe depressive symptom levels (Baert, De Raedt, & Koster, 2010). Despite this limitation, the reported findings remain of importance because individuals with subclinical symptom levels experience significant suffering and are at risk to develop clinical depression. The emotional biases in attention, interpretation, and memory are likely to contribute to this pathogenesis (Gotlib & Joormann, 2010).

Second, the specificity of our findings to depression may be limited by the high correlations between trait anxiety and depressive symptom severity we observed in most studies. Indeed, anxiety and depression frequently co-occur (Kessler & Wang, 2009) which could be explained by the substantial symptom overlap (e.g., rumination versus worry, poor sleep quality) and the shared environmental (e.g., loss), biological, and cognitive factors that may underlie symptoms of anxiety

and depression (Hong & Cheung, 2014; Mineka, Watson, & Clark, 1998). Although high comorbidity rates are widely acknowledged, few studies have investigated its impact on emotional processing biases. While comorbidity may not play a major role in threat-related attention bias (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007), there is evidence that emotional memory biases differ in anxious versus depressed individuals (Mitte, 2008). The little research that has tested effects of the comorbidity of anxiety and depressive disorders observed that the attention biases for subliminally presented stimuli predicted recognition of emotional material only for socially anxious individuals with comorbid major depression (LeMoult & Joormann, 2012). These results suggest that the presence of comorbidity affects the interplay between attention and memory biases. Further research needs to elucidate the role of comorbidity in the interplay between emotional biases in attention, interpretation, and memory. Regardless of the limited depression specificity, our findings inform on naturally occurring interactions between cognitive biases that may cut across common mental disorders.

Third, as is noted throughout different chapters of this doctoral dissertation, direct proof of the causal direction of effects requires experimental manipulation of one cognitive bias to examine its effects on other cognitive processes. Certain features of the developed study designs may have the optimized conditions to test the effect of one cognitive bias on another process (e.g., instructions, temporal order of tasks, and the use of similar stimulus materials across tasks) and allow some confidence in the modeled relations between biases. However, possible third variables may account for the observed relations in the cross-sectional studies and caution is warranted with regard to our conclusions about the direction of effects. Future research will need to provide a formal test of the assumed direction of effects using cognitive

bias modification or cognitive training methods (see ‘triangulating research findings’).

A last limitation concerns the measures of attention bias (e.g., eye movement registration, performance-based measures such as RTs) employed in this doctoral dissertation research which solely relied on visual attention. As a consequence, our findings shed light on how external attention is related to internal cognitive processes, and provide limited insight into internal attention mechanisms. Although there may be a high correspondence between overt (e.g., assessed by eye tracking) and covert (e.g., assessed by a Posner cueing task) attentional shifts and their relation with other cognitive processes (e.g., interpretation), covert shifts in attention can occur without overt attentional shifts (Weierich, Treat, & Hollingworth, 2008). This issue seems particularly important to interpret the results regarding the role of sustained (external) attention during memory retrieval, which provide limited insight into internal attention processes that could be involved in memory search. Although external attentional mechanisms are likely to regulate the focus of internal attention, further research should address whether the relations between cognitive biases reported here generalize to the internal attention domain (see ‘unravelling interactions between cognitive biases’).

Future Directions and Challenges

Unravelling Interactions Between Cognitive Biases

Although research on interactive cognitive biases has made considerable progress, several aspects of attention – memory bias interactions have not received much empirical attention yet. In addition to previously outlined recommendations (Everaert, Koster, & Derakshan, 2012) and the abovementioned open issues, below we delineate four exciting lines of research to invite further empirical scrutiny in order to gain a fuller understanding of how emotional attention controls and is controlled by memory biases in depression.

A first line of for future research should continue efforts to understand how attentional biases during encoding modulate the formation of emotional memories. Present research has improved our understanding of how emotionally biased attentional mechanisms during encoding of emotional interpretations are related to consciously retrieved experiences probed by explicit memory tasks (see chapters 1 and 2). As a result, much less is known about the interplay between emotional biases in attention at encoding and implicit memory. It is not clear, for example, whether emotional biases in attentional selection versus sustained attention during encoding contribute to implicit memory in a similar or different manner as the attentional mechanisms that modulate encoding into explicit memory. It seems plausible that aspects of an emotional experience must be selected from other competing stimuli to be encoded into implicit memory (Chun & Turk-Browne, 2007), but the modulatory role of sustained attention bias during encoding in explicit memory may be different for implicit remembering. Moreover, most studies have examined memory bias in terms of the content that is retrieved without investigating how encoding alters the associations between memories. This would cast light on how new emotional material is integrated into existing associative memory networks. Recent innovations in network analysis may provide ways to test how attention biases impact associative memory networks (Borsboom & Cramer, 2013).

A second important avenue for future study is to elucidate the role of attention during retrieval of emotional memories. Investigators have recently started to investigate interactions between visual attention and memory retrieval of emotional items, yielding support for the role of sustained attention bias toward external cues in guiding the internal process of controlled retrieval (see chapter 2). Although a close relation seems likely, the interactions between external and internal attention biases during conscious memory retrieval of emotional

material are not well understood. It is not clear, for example, how external cues impact internal processes (e.g., is external input used to generate internal search cues?) and if these in turn shape external attention (e.g., selection of relevant visual input to further guide retrieval). More research that manipulates external visual input and internal attentional resources is needed to disentangle the role of external and internal attention in guiding memory retrieval. While controlled retrieval may involve sustained attentional mechanisms, the regulating factors in automatic emotional memory retrieval are currently not known. It is plausible, for example, that the external stimuli that capture attention may directly activate a memory trace without requiring an elaborative search process. Further empirical study could examine eye-tracking parameters such as first fixation locations and durations in relation to familiarity-based memory biases to cast light on the necessity of attention for automatic memory retrieval.

A third line of research needs to consider how explicit and implicit memory systems contribute to emotional attention. Initial experiments have reported encouraging evidence for memory-guided attention effects that depend on the attentional mechanism, the stimulus exposure duration, and the valence of the emotional memory associations (see chapter 3). Still, many open questions need to be addressed to understand how emotional memory shapes attention. For instance, it has not yet been explored how emotionally positive versus negative knowledge stored in long-term memory can be used to guide attention in controlled, goal-directed search for certain emotional information. Also not much is known about whether implicitly acquired knowledge (e.g., via statistical learning) has the ability to guide attention toward regularities in emotionally positive versus negative material. Moreover, it remains uninvestigated whether implicit knowledge hinders explicit memory-based effects on goal-directed

attention. Here, a comparison of the temporal profile of implicit versus explicit memory-based effects on attention bias would be highly informative. These open issues currently challenge our understanding of emotional memory-guided attention effects and this provides an interesting direction for further research.

A fourth line of studies should identify the role of cognitive control in regulating emotional biases in attention, interpretation, and memory. Difficulties in inhibition, shifting, and updating are thought to operate as overarching mechanisms across depression-related biases in attention, interpretation, and memory (Joormann et al., 2007). Studies have confirmed the link between aspects of cognitive control and depression (De Lissnyder et al., 2012; Derakshan, Salt, & Koster, 2009; Goeleven, De Raedt, Baert, & Koster, 2006), but the hypothesis that cognitive control deficits explain emotional biases in cognitive processes has yet to be tested. It is currently unclear whether distinct control processes have differential relations with attention, interpretation, and memory biases. Research needs to address whether aspects of cognitive control have direct or indirect (e.g., via attention) relations with interpretation and memory biases. The role of cognitive control deficits in relation to cognitive biases should be considered in both encoding and retrieval contexts when differentiating between explicit and implicit memory systems. Furthermore, future studies also need to examine how cognitive control processes are involved in implicit versus explicit memory-guided attention effects (e.g., can control processes override implicit guidance effects?). These unanswered questions present important goals for future research.

The insights gained as a result of empirical efforts to address the lingering issues in research on attention – memory bias interactions will inform the development of more sophisticated theoretical models of depression. While contemporary clinical theories do often not have the level of specificity in their predictions to guide research on this

topic, future work may be inspired by more basic science models and tools to investigate internal versus external attention (Chun et al., 2011), factors during encoding and retrieval (Chun & Turk-Browne, 2007; Talmi, 2013), as well as memory-guided attention effects (Hutchinson & Turk-Browne, 2012). More cross-talk between the research domains of cognitive science, neuroscience, emotion science, and clinical cognition may provide opportunities for cross-fertilization such that clinical research can benefit from validated cognitive models and cutting-edge experimental paradigms, and basic, theoretical research may in turn find clinically relevant applications.

Triangulating Research Findings

The majority of investigations testing relations between attention, interpretation, and memory has been conducted in samples of healthy or subclinically depressed people delivering findings that may not describe well the interplay between cognitive biases occurring in non-depressed at-risk, currently, or formerly depressed people. This prompts researchers to address the outlined research questions that emerge from the combined cognitive biases hypothesis in the different groups of healthy and depressed individuals. Increasing the diversity in study samples seems important because the interplay among emotionally biased cognitive processes may change as a function of the experience of being depressed (e.g., intensifying sad affect and negative thinking), potentially affecting the strength of one or more negative cognitive biases (e.g., memory) and its relations with other processes (e.g., memory-based effects on attention). If more research considers the interplay among cognitive biases in samples drawn from non-depressed and formerly depressed at-risk populations as well as currently depressed populations, investigators can learn about potential similarities and differences in the interactions across sample types, the interconnectivity among cognitive biases (i.e., the strength of the relations), and their relations with depressive symptom severity.

To uncover interactions between emotionally biased cognitive processes within the different sample types, investigators have various research designs at their disposal. At present, most studies adopted a cross-sectional design to test associations between cognitive biases, few studies used cognitive training methods to investigate the direction of the observed effects, and even fewer studies employed longitudinal designs to examine combined effects of multiple biases. Yet, a thorough examination of the combined cognitive biases hypothesis requires a methodological approach that implements each of these complementary research designs to tackle association, causal, and predictive magnitude questions (Everaert et al., 2012).

Cross-sectional research methodologies can be designed to test specific relations between multiple cognitive biases during specific mental operations such as encoding and retrieval of emotional material. This type of study design, however, precludes conclusions regarding causality because third unknown variables could account for the observed relations. This issue of cause-and-effect can be solved by applying cognitive training methods that manipulate emotional biases in targeted processes in an experimental manner (Koster, Fox, & MacLeod, 2009). Although existing training methodologies are useful, the mechanisms underlying training procedures are currently not well understood and many of the available procedures are not able to target a very specific set of cognitive processes. For example, there are no methods to manipulate an emotional bias in explicit or implicit memory to examine its effects on attention. Both cross-sectional and cognitive training study designs inform on the interplay between cognitive biases in relation to depressive symptoms at a specific point in time, leaving unaddressed how cognitive biases develop and change over time to impact depressive symptoms. Longitudinal study designs extend beyond a single moment in time and are able to cast light on each of these issues. As cognitive training methods, findings from longitudinal

research provide some indication about cause-and-effect relations that may exist between cognitive biases.

Cross-sectional, cognitive training, and longitudinal research designs have their own strengths and pitfalls, but if combined, they provide complementary approaches to examine the interplay between cognitive biases in relation to emotional well-being. Advanced knowledge about the interplay between cognitive processing biases gained from cross-sectional and cognitive training methods may help to explain findings from longitudinal research (e.g., the best cognitive marker is the weakest link), which may in turn guide research within proximal timeframes (e.g., by pointing to the importance of mapping out individual cognitive profiles for cognitive training purposes). In order to gain a comprehensive understanding of interactive cognitive biases in depression, we argue for an approach that triangulates research findings from cross-sectional, cognitive training, and longitudinal research methodologies and samples including healthy, non-depressed at-risk, currently, and formerly depressed people.

Recent Research Advances in Clinical Cognition

Several recent conceptual and methodological innovations in research on cognitive processing biases hold great potential to further our understanding of the interplay among emotionally biased cognitive processes and their impact depressive symptoms. Two promising trends are discussed in turn.

The dynamic expression of psychological processes

Investigators increasingly conceptualize cognitive biases and emotional responding as context-dependent and time-sensitive psychological phenomena. Indeed, the context and timing when cognitive biases operate and emotional responses are elicited differs within and across individuals (Koval et al., 2013; Zvielli, Bernstein, & Koster, 2014). However, the complexity of the nature of the phenomena

under study is rarely acknowledged in investigations of depression-related biases in cognitive processes.

Modeling fluctuations in between cognitive biases in time may provide better insights into the dynamic expression of cognitive biases and their interactions. Here, the trial-level bias score approach provides several novel parameters to quantify the expression of attention bias in time (Zvielli et al., 2014). It allows investigation of attentional biases at the trial level by visualizing the degree to which the average trial-level bias score is greater than zero, the phasic expression of attention bias, as well as the stability or variability in the expression of attention bias. This analytical strategy holds great potential as a tool to further our insight into relations between cognitive biases. More specifically, if we can link such time-sensitive indices to performance on interpretation and memory tasks, we may gain a better understanding of the attentional mechanisms that regulate which stimuli are encoded and remembered as well as memory-guided attention effects.

Not only may cognitive biases and their mutual influences fluctuate in time, they are also likely to be context-dependent. Depending on an individual's personal concerns, the negative bias in basic cognitive processes and the strength of their relations may be variable. For instance, a depressed individual may recall examples why he/she is a failure at work while he/she is able to remember prior situations when being a good partner. These concern-related memory biases may change in function of mood states or distressing events (e.g., when having problems in the romantic relationship or when being flooded with work). Also in the lab very few depressed individuals solely process negative material in the presence of positive or neutral stimuli when performing cognitive-experimental tasks. This suggests that some stimuli may not tap into an individual's personal concerns at that time. A majority of these cognitive tasks present participants with a series self-referent words (e.g., winner, loser) they need to process

(un)intentionally. Although this provides some information on general tendencies in attention allocation or encoding/retrieval at the time of measurement, it provides suboptimal insight into how people process emotional material that is relevant to them at a certain moment (e.g., ‘I am a loser in my job’, ‘I am a winner at doing sports’). In this regard, we think that some of the paradigms used in this doctoral dissertation provide a way to address this lack-of-context issue. Combining eye movement registration with a scrambled sentences test as an elaborative encoding task provides attentional bias measures that are sensitive to the context as set out by the individual scrambled sentences (e.g., born I winner am loser a). This type of study designs may provide a more accurate estimation of cognitive biases and their relations. We hope that this approach may inspire the future development of new experimental tasks to test core aspects of the combined cognitive biases hypothesis.

Online measurement of psychological processes

Researchers are also increasingly using online measures of cognitive processing biases (e.g., attention) while participants are performing a targeted mental operation, such as encoding (see chapter 1), reappraisal (Manera, Samson, Pehrs, Lee, & Gross, 2014), or retrieval (see chapter 1) of emotional material. In contrast to traditional approaches that measure attention bias in a separate task, the emerging ways to measure attention allocation during an assigned task (e.g., scrambled sentences test) are likely to capture more of the action. Indeed, individuals actively select competing positive and negative information to guide the active process of interpretation, reappraisal, or retrieval. Measures of attentional mechanisms (e.g., obtained via eye tracking) when participants are actively engaged in a task may better reflect the nature of the cognitive bias compared to measures drawn from a separate attentional bias task in which individuals passively view task-(ir)relevant stimuli.

Concluding Remarks

Attention, interpretation, and memory biases are overlapping processes that operate continuously and with mutual relations to predict prospective changes in depressive symptoms. Our work has unlocked some parts of the complex interplay between emotionally biased cognitive processes. Yet, much remains to be discovered about how attention biases control and are controlled by emotional memory representations. Only by improving our understanding of the proximal and distal relations among cognitive biases in attention, interpretation, and memory, we can gain a comprehensive understanding of the cognitive foundations of healthy and disordered emotional functioning.

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% Author: Jonas Everaert

% Date: 19/02/15

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"Final_dataset_Everaert_cognition&emotion_2013.sav"
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% Interactions between emotional attention, encoding, and retrieval of ambiguous information: An eye-tracking study.

% Author: Jonas Everaert

% Date: 19/02/15

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2. Information about the datasets to which this sheet applies

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* Reference of the publication in which the datasets are reported:
 Everaert, J., & Koster, E.H.W. (in press) The interaction between emotional attention, encoding, and retrieval of ambiguous information: An eye-tracking study. *Emotion*. doi:
 10.1037/em00000063.

* Which datasets in that publication does this sheet apply to?: This sheet applies to the only data described in the article..

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3b. Other files

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- file(s) containing processed data. Specify: the processed data is presented in "final data set Emotion2015.sav".
- file(s) containing analyses. Specify: "analyses_Emotion2015.spv" and "Everaert_Koster_attention_retrieval_Emotion2015.pdf".
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- affiliation:
- e-mail:

% **Remembering to attend**

% Author: Jonas Everaert

% Date: 19/02/15

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* Reference of the publication in which the datasets are reported:
 Everaert, J. (2015). Remembering to attend. Chapter 3 in PhD dissertation.

* Which datasets in that publication does this sheet apply to?: Data from two studies is described in this chapter. There is one dataset for each experiment.

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- other (specify): responsible ZAP PC, collaborators (prof. dr. Nicholas Turk-Browne, drs. Judith E. Fan)

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3b. Other files

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- file(s) containing processed data. Specify: "MGAcolor_exp1.sav", "mga_endiseng_fullsample_exp2.sav"
- file(s) containing analyses and results. Specify: "output_exp1.spv", "output_exp2.spv"
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- address:
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- e-mail:

% Attention bias modification via single-session dot-probe training: Failures to replicate.

% Author: Jonas Everaert
 % Date: 19/02/15

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2. Information about the datasets to which this sheet applies

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* Reference of the publication in which the datasets are reported:
 Everaert, J., Mogoase, C., David, D., & Koster, E.H.W. (in press).
 Attention bias modification via single-session dot-probe training:
 Failures to replicate. *Journal of Behavior Therapy and Experimental
 Psychiatry*. doi: 10.1016/j.jbtep.2014.10.011.

* Which datasets in that publication does this sheet apply to?: Data from three studies is described in this article. There is one dataset for each experiment.

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- other (specify): responsible ZAP PC and Cristina Mogoase (collaborator)

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3b. Other files

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- file(s) describing the transition from raw data to reported results. Specify: A detailed description can be found in the article.
- file(s) containing processed data. Specify: processed data for exp1 is with Cristina Mogoase, "processing_ABM_RTsheet_exp2.xlsx", "Final_dataset_JBTEP2015_exp2.sav", "Final_dataset_JBTEP2015_exp3.sav",
- file(s) containing analyses and results. Specify: "Output1_exp2.spv", "Output1_exp3.spv", for experiment 1 contact Cristina Mogoase.
- files(s) containing information about informed consent
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- name:
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% Emotional attention during instructed and uninstructed ambiguity resolution in relation to depressive symptoms

% Author: Jonas Everaert

% Date: 19/02/15

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1a. Main researcher

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- address: Henri Dunantlaan 2, B-9000 Gent
- e-mail: alvaro.sanchezlopez@UGent.be; jonas.everaert@ugent.be

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- e-mail: ernst.koster@ugent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

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* Reference of the publication in which the datasets are reported:
 Sanchez, A., Everaert, J., De Putter, L., Mueller, S., & Koster, E.H.W.
 Life is...great! Emotional attention during instructed and uninstructed
 ambiguity resolution in relation to depressive symptoms. Biological
 Psychology. doi:10.1016/j.biopsycho.2015.04.007

* Which datasets in that publication does this sheet apply to?: This sheet applies to the only dataset described in the article.

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- file(s) containing processed data. Specify: "+DataSet SST study 1 final.sav"
- file(s) containing analyses and results. Specify: "1.Output Model Ability Dep_Att_Int.spv", "1.Output Model Tendency Dep_Att_Int.spv", "2.Output Model Ability Dep_Int_Att.spv", "2.Output Model Tendency Dep_Int_Att.spv", "3.Output Model Ability Att_Int_Dep.spv", "3.Output Model Tendency Att_Int_Dep.spv", "4.Output Model Ability Int_Att_Dep.spv", "4.Output Model Tendency Int_Att_Dep.spv", "5. Output Correlations (included RTs).spv"
- files(s) containing information about informed consent
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% Emotionally biased cognitive processes: The weakest link predicts prospective changes in depressive symptoms

% Author: Jonas Everaert

% Date: 10/04/15

1. Contact details

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1a. Main researcher

 - name: Jonas Everaert
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 - e-mail: jonas.everaert@ugent.be

1b. Responsible Staff Member (ZAP)

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 * Reference of the publication in which the datasets are reported:
 Everaert, J., Duyck, W., & Koster, E.H.W. (2015). Emotionally biased cognitive processes: The weakest link predicts prospective changes in depressive symptoms. *PloS One*. doi: 10.1371/journal.pone.0124457.

* Which datasets in that publication does this sheet apply to?: This sheet applies to the only data described in the article.

3. Information about the files that have been stored

3a. Raw data

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- other (specify): responsible ZAP PC, the data is available on figshare (doi: <http://dx.doi.org/10.6084/m9.figshare.1340003>)

* Who has direct access to the raw data (i.e., without intervention of another person)?

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- other (specify): there are no access restrictions. The data is available on figshare <http://dx.doi.org/10.6084/m9.figshare.1340003>

3b. Other files

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Nederlandstalige Samenvatting¹

Stel je voor: je bevindt je in een sollicitatiegesprek voor een felbegeerde baan. Terwijl je op de vragen van de commissieleden antwoordt, merk je dat het ene commissielid glimlacht en knikkend luistert en een ander commissielid fronsend naar achteren leunt. Afhankelijk van waar je aandacht naar toe wordt getrokken zal je andere interpretaties als aannemelijk beschouwen. Indien aandacht zich selectief richt op het glimlachende commissielid zullen interpretaties als “ik maak een goede indruk en heb kans op de baan” waarschijnlijk zijn, terwijl interpretaties als “ik maak er helemaal niets van en kan het wel vergeten” eerder geloofwaardig zijn wanneer aandacht zich selectief richt op het fronsende commissielid. De ervaren emoties zullen bijgevolg zeer verschillend zijn. Op deze manier zijn aandachtsprocessen eveneens bepalend bij de wijze waarop de ervaring van het sollicitatiegesprek in het geheugen zal worden opgeslagen en herinnerd zal worden als een positieve of negatieve gebeurtenis. Dit voorbeeld illustreert dat aandacht, interpretatie en geheugen nauw gerelateerd zijn aan allerlei emoties. Hoe emotionele vertekeningen in deze cognitieve processen gerelateerd zijn aan veelvoorkomende psychiatrische stoornissen zoals depressie werd dan ook uitvoerig wetenschappelijk onderzocht.

¹ Based on Everaert, J., & Koster, E.H.W. (in press). Vastzitten in depressie: De vicieuze cirkel van informatieverwerking. *De Psycholoog*.

Kwetsbaarheidsfactoren Voor Depressie

Onderzoek heeft aangetoond dat emotionele vertekeningen in aandacht, interpretatie en geheugen van belang zijn bij het ontstaan en voortbestaan van depressieve klachten (Gotlib & Joormann, 2010). Studies hebben uitgewezen dat er bij depressieve personen negatieve vertekeningen voorkomen in deze cognitieve processen. Concreet wil dit zeggen dat personen die kampen met depressie moeilijkheden ervaren bij het loskoppelen van hun aandacht voor negatieve aspecten uit de omgeving en minder aandacht hebben voor positieve aspecten (vb.: het fronsende vs. het glimlachende commissielid) (De Raedt & Koster, 2010; Peckham, McHugh, & Otto, 2010). Verder zullen depressieve personen ook vaker ambigue situaties op een negatieve wijze interpreteren (vb.: door de houding van het fronsende en niet het glimlachende commissielid te betrekken op de eigen prestatie) (Wisco, 2009) en zich meer negatieve dan positieve gebeurtenissen herinneren (vb.: tijdens het sollicitatiegesprek kan men zich een vorige faalervaring en geen succeservaring herinneren) (Gaddy & Ingram, 2014; Matt, Vazquez, & Campbell, 1992). Figuur 1 illustreert deze cognitieve vertekeningen.

Vertekende cognitieve processen verlopen betrekkelijk automatisch en komen zowel voor bij subklinisch, klinisch als bij voorheen depressieve personen (Dearing & Gotlib, 2009; Hedlund & Rude, 1995; Kujawa et al., 2011). Daarenboven voorspellen deze processen de emotionele reactie op stressvolle gebeurtenissen (Clasen, Wells, Ellis, & Beevers, 2013; Ellenbogen, Schwartzman, Stewart, & Walker, 2002; Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013) en de toename in depressieve symptomen (Beevers & Carver, 2003; Johnson, Joormann, & Gotlib, 2007; Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002). Emotionele vertekeningen in aandacht, interpretatie en geheugen kunnen daarom beschouwd worden als kwetsbaarheidsfactoren voor de stoornis.

Ondanks een sleutelrol voor cognitieve vertekeningen bij het begrijpen en verklaren van depressie bevindt het wetenschappelijk onderzoek naar de relaties tussen deze processen zich in een vroeg stadium (Everaert, Koster, & Derakshan, 2012). Het huidige onderzoek richt zich voornamelijk op het aantonen van emotionele vertekeningen waarbij er meestal onderzoek werd gevoerd naar de invloed van één proces, hetzij aandacht, interpretatie of geheugen. Het lijkt echter noodzakelijk om na te gaan hoe deze cognitieve vertekeningen elkaar beïnvloeden om tot een grondig begrip te komen van de cognitieve basis van depressie.

Cognitieve Vertekeningen: Communicerende Vaten?

Enkele belangrijke vragen over de wisselwerking tussen cognitieve vertekeningen die tot op heden onbeantwoord bleven zijn immers: (1) hoe zorgen negatieve aandachts- en interpretatievertekeningen ervoor dat stemmingscongruente informatie wordt opgeslagen in het geheugen, (2) spelen aandachtsvertekeningen een rol bij het selectief herinneren van emotionele ervaringen, (3) kunnen emotionele herinneringen de aandacht richten naar stemmingscongruente informatie in de omgeving, en (4) hoe voorspellen aandachts-, interpretatie- en geheugenvertekeningen in combinatie het verdere verloop van depressiesymptomen. Deze vragen hebben we bestudeerd met een reeks wetenschappelijke experimenten en hieronder zullen we de belangrijkste bevindingen bespreken.

Aandachtsvertekeningen Bepalen Emotionele Interpretaties en Herinneringen

In een eerste studie (Everaert, Duyck, & Koster, 2014) voerden personen met minimale en ernstige depressiesymptomen een computertaak uit waarbij ze vervormde zinnen (vb.: “ben verliezer ik geboren winnaar een”) hervormden naar goed lopende zinnen door het positieve of negatieve woord weg te laten. De oplossing kon telkens

leiden tot een positieve of een negatieve betekenis (vb.: “ik ben een geboren winnaar” vs. “ik ben een geboren verliezer”). Telkens dienden de deelnemers de eerste oplossing te rapporteren die in hun gedachten opkwam. Dit leverde een maat voor interpretatievertekening. Om aandachtsvertekeningen te meten werden oogbewegingen van de deelnemers geregistreerd tijdens het uitvoeren van de interpretatietaak. We registreerden hoe lang (maat voor volgehouden aandacht) en hoe vaak (maat voor aandachtselectie) ze keken naar positieve (vb.: winnaar) en negatieve (vb.: verliezer) woorden. Na deze taak werden de deelnemers gevraagd om zoveel mogelijk zinnen te herinneren die men had gevormd. Dit leverde een maat voor geheugenvertekening. Figuur 2 toont een schematische weergave van de interpretatietaak.

De analyse toonde aan dat de manier waarop iemand aandacht richtte naar emotionele woorden de aard van de interpretaties voorspelde. Personen die vaker hun aandacht richtten naar negatieve woorden in vergelijking met positieve woorden (aandachtselectie), maakten meer negatieve interpretaties en rapporteerden vervolgens ook meer negatieve herinneringen. Ook naarmate iemand langer keek naar de negatieve woorden (volgehouden aandacht) tijdens het interpreteren herinnerde men zich meer negatieve betekenissen. In overeenkomst met vorig onderzoek vonden we dat negatieve vertekeningen in aandacht, interpretatie en geheugen gerelateerd zijn aan depressiesymptomen (Gotlib & Joormann, 2010). Hoe ernstiger de symptomen, hoe sterker de negatieve vertekening.

Negatieve aandachtsvertekeningen spelen dus een rol bij het selectief interpreteren van nieuwe informatie wat vervolgens bepaalt wat iemand zich herinnert. Deze bevinding werd bevestigd in een replicatieonderzoek (Everaert, Tierens, Uzieblo, & Koster, 2013) en is in overeenstemming met vorig onderzoek naar de link tussen

geheugen en interpretatie, en tussen geheugen en aandacht (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013; Everaert et al., 2012; Joormann, Waugh, & Gotlib, 2015).

Als aandachtsvertekeningen de verwerking van nieuwe emotionele interpretaties in het geheugen kunnen beïnvloeden, dan is een logische volgende vraag wat hun rol is tijdens het herinneren van oude, voordien opgeslagen emotionele interpretaties. Dit hebben we onderzocht in een experiment bij een gezonde steekproef (Everaert & Koster, 2015). Tijdens een eerste taak hervormden de deelnemers opnieuw vervormde zinnen naar goed lopende zinnen (zie figuur 2). In een daaropvolgende geheugentaak werd een reeks woordparen getoond waarbij deelnemers telkens bepaalden of de gepresenteerde woorden in de vorige taak werden gebruikt om een zin te maken. De helft van de woordparen was eerder gezien ‘oud’ (vb.: winnaar – verliezer), de andere helft was ‘nieuw’ (vb.: depressief – opgewekt). Via een specifieke antwoordprocedure was het mogelijk om een onderscheid te maken tussen automatische, onbewuste en gecontroleerde, bewuste processen die betrokken kunnen zijn bij het herinneren van emotionele informatie (Tulving, 1985; Yonelinas, Aly, Wang, & Koen, 2010). Om de rol van vertekeningen in aandachtselectie en volgehouden aandacht na te gaan werden oogbewegingen van de deelnemers geregistreerd tijdens de presentatie van de woordparen.

De resultaten toonden aan dat emotionele vertekeningen in volgehouden aandacht, niet in aandachtselectie, naar de negatieve woorden uit de woordparen gerelateerd waren aan vertekeningen in de herinnering van de emotionele betekenissen. Dit betekent dat naarmate men langer keek naar negatieve woorden, men zich meer negatieve interpretaties herinnerde. Dit resultaat werd gevonden ook na controle voor de initiële vertekeningen in de interpretatie (de geselecteerde betekenis) en was specifiek voor gecontroleerde,

bewuste en niet voor automatische, onbewuste geheugenprocessen. Emotionele vertekeningen in de aandacht spelen dus niet enkel een rol bij het interpreteren van nieuwe emotionele informatie maar ook bij het bewust, gericht zoeken naar emotionele herinneringen.

Emotionele Herinneringen Sturen de Aandacht

Terwijl het merendeel van het onderzoek naar relaties tussen cognitieve vertekeningen zich toegeleefd heeft op het bestuderen van hoe vertekeningen in de aandacht of interpretatie tijdens vroege stadia van informatieverwerking een invloed hebben op het geheugen, is er tot op heden weinig bekend over het omgekeerde effect. Het is onduidelijk of het emotionele geheugen de aandacht kan sturen. Aan deze leemte wilden we tegemoet komen.

In een eerste studie voltooiden deelnemers een aandachtstaak na een leer fase waarbij ze willekeurig gegenereerde kleuren leerden associëren met blijde, neutrale of boze gelaatsexpressies. Tijdens de aandachtstaak werden paren van gekleurde cirkels gepresenteerd waarvan één cirkel met neutrale associaties en de andere met emotionele (negatieve of positieve) associaties. In elke cirkel werd een lijnstuk met een verticale of geroteerde oriëntatie gepresenteerd. De deelnemers dienden zo snel mogelijk het geroteerde lijnstuk te vinden. De aanwezigheid van de gekleurde cirkels was dus irrelevant voor het correct uitvoeren van de taak. We kunnen stellen dat wanneer emotionele associaties de aandacht trekken, de deelnemers het geroteerde lijnstuk sneller zouden vinden wanneer het verschijnt in de cirkel met emotionele associaties dan wanneer het geroteerde lijnstuk zou verschijnen in de cirkel met neutrale associaties. Figuur 3 toont de experimentele procedure.

We vonden een algemeen effect waarbij deelnemers het geroteerde lijnstuk sneller detecteerden wanneer het werd gepresenteerd binnen een gekleurde cirkel met positieve associaties. Dit geeft aan dat aandacht wordt gericht naar stimuli met positieve

associaties. Deze bevinding is in overeenstemming met onderzoek waarin gevonden werd dat aandacht vertekend is naar stimuli die geassocieerd werden met beloning (Anderson, Laurent, & Yantis, 2011; Hickey & van Zoest, 2013). Het algemene effect hing samen met depressiesymptomen. De positieve aandachtsvertekening was sterker bij personen met lage depressiesymptomen en zwakker bij personen met verhoogde depressiesymptomen.

In een tweede experiment bij gezonde deelnemers werden specifieke componenten van de aandachtstaak gemanipuleerd om te onderzoeken welke aandachtsprocessen werden beïnvloedt en wat het tijdsverloop was van de geheugeneffecten op aandacht. Hier vonden we dat negatieve geheugenassociaties een invloed hadden op aandachtsselectie en niet op volgehouden aandacht bij een korte presentatieduur van de gekleurde cirkels. Aandacht was minder vertekend naar stimuli met negatieve associaties. Er werden geen effecten gevonden bij de verwerking van positieve informatie.

Deze studies tonen aan dat eerder geleerde emotionele associaties de aandacht kunnen sturen. Dit effect blijkt afhankelijk te zijn van de valentie van de geheugenassociaties, presentatieduur van de stimulus en specifieke aandachtsprocessen. Belangrijk is dat in elk van de experimenten de effecten gedreven werden door de associaties met de kleuren en niet door een positieve of negatieve evaluatie van de gekleurde cirkels.

De Zwakste Schakel Voorspelt Depressiesymptomen

Studies hebben uitgewezen dat vertekeningen in aandacht, interpretatie en geheugen symptomen van depressie voorspellen (Beevers & Carver, 2003; Johnson et al., 2007; Rude et al., 2002). Het blijft echter onduidelijk hoe combinaties van cognitieve vertekeningen het verloop van depressie beïnvloeden. Om dit te onderzoeken werden de deelnemers uit een eerder onderzoek na één jaar opnieuw gecontacteerd (Everaert, Duyck, & Koster, 2015). Bij deze follow-up

werd de ernst van depressiesymptomen opnieuw gemeten alsook de stress ervaren tijdens de laatste maand voor de meting.

Om de gezamenlijke impact van cognitieve vertekeningen te modelleren werd gebruik gemaakt van verschillende conceptuele modellen die relaties tussen de processen specificeren (Abela & Hankin, 2008). Een eerste model, het *additieve model*, veronderstelt dat cognitieve vertekeningen een cumulatieve invloed hebben. Dit wil zeggen dat de kans op depressie toeneemt naarmate iemand meer negatieve cognitieve vertekeningen heeft. Een tweede model, het *zwakste schakel model*, stelt dat het meest negatief vertekende proces de beste voorspeller is voor depressie. Deze studie testte of deze modellen, afzonderlijk en in wisselwerking met ervaren stress, longitudinale veranderingen in depressiesymptomen konden voorspellen.

We vonden dat zowel het additieve als het zwakste schakel model veranderingen in de ernst van depressiesymptomen na één jaar konden voorspellen. Bij een rechtstreekse vergelijking van de modellen bleek dat het zwakste schakel model een betere voorspeller was. Voor beide modellen was de wisselwerking met stress niet significant. Deze resultaten geven aan dat de beste cognitieve predictor van symptomen van depressie dat proces is met de sterkste vertekening naar negatieve informatie. De aard van dit proces (hetzij aandacht, interpretatie of geheugen) kan per individu verschillend zijn.

Conclusie

Onderzoek toont aan dat negatieve vertekeningen in aandacht, interpretatie en geheugen gerelateerde cognitieve processen zijn. Aandachtsvertekeningen beïnvloeden de emotionele inhoud van herinnerde interpretaties via hun rol bij het opslaan en ophalen van informatie uit het geheugen. Op hun beurt kunnen emotionele associaties in het geheugen de aandacht naar aspecten uit de

omgeving sturen. Aandachts-, interpretatie- en geheugenvertekeningen hebben in combinatie een impact op het verloop van depressiesymptomen waarbij de zwakste schakel de beste voorspeller is.

Klinische Implicaties

Emotie(dis)regulatie

Kennis over de wisselwerking tussen cognitieve vertekeningen werpt licht op de mechanismen die aan de basis liggen van problemen bij de emotieregulatie die kenmerkend zijn voor depressie. Depressieve personen zullen vaker rumineren of stilstaan bij de oorzaken en gevolgen van depressieve gevoelens, minder vaak hun negatieve interpretaties herzien noch positieve herinneringen ophalen om hun negatieve stemming te doorbreken (Joormann & D'Avanzato, 2010).

Wanneer men zich in een stressvolle situatie bevindt (vb.: een sollicitatiegesprek), zullen depressieve personen vaker en langer hun aandacht richten naar negatieve aspecten uit de omgeving (vb.: het fronsende commissielid). De moeilijkheden bij het loskoppelen van aandacht naar negatieve informatie ondermijnen het heroriënteren van aandacht naar positieve signalen (vb.: het glimlachende commissielid) als een emotieregulatie strategie en zal veelal leiden tot negatieve interpretaties van de situatie (vb.: “ze zullen denken dat ik niet geschikt ben voor de baan”). Negatieve vertekeningen in de aandacht en interpretatiestijl kunnen verhinderen dat men de situatie opnieuw gaat herinterpreteren op een minder negatieve wijze (vb.: “het was zo slecht nog niet”). Dit proces kan disfunctionele opvattingen in het geheugen of schema's bekrachtigen (vb.: “ik ben waardeloos”) en andere, gerelateerde herinneringen activeren (vb.: herinneringen aan een stukgelopen relatie) die het negatieve denken (rumineren) kunnen versterken. Door deze negatief vertekende verwerking van emotionele informatie worden er ook meer negatieve

ervaringen in het geheugen opgeslagen, wat het gebruik van positieve herinneringen om de negatieve stemming te reguleren in de toekomst ondermijnt. Daarnaast kunnen negatieve signalen uit de situatie ook gemakkelijk negatieve herinneringen activeren (vb.: “mijn laatste interview ging ook helemaal mis”), wat op zijn beurt de aandacht kan sturen naar andere negatieve signalen. Dit kan de negatieve interpretaties bevestigen en herinterpretatie bemoeilijken. Hierdoor is de cirkel rond.

Door de wisselwerking tussen cognitieve vertekeningen en emotieregulatie strategieën kunnen depressieve personen vastzitten in een vicieuze cirkel van toenemend negatief denken en negatief affect. Het stelselmatig gebruik van specifieke emotieregulatie strategieën zoals ruminatie (voortdurend piekeren over de oorzaken en gevolgen van de negatieve gevoelens: “hoe komt het dat ik ongelukkig ben”) kan op termijn specifieke cognitieve vertekeningen versterken (vb.: aandacht voor negatieve informatie). Door dit wederkerig proces kan er zich een zwakke cognitieve schakel ontwikkelen die een voorspeller is van depressieve symptomen.

Deze inzichten zijn niet louter van theoretisch belang omdat therapeutische interventies (vb.: cognitief herstructureren) vaak een beroep doen op emotieregulatie vaardigheden bij patiënten (vb.: herinterpretatie, stemming incongruente herinnering). Uit het voorgaande blijkt dat het gebruik van emotieregulatie strategieën bemoeilijkt kan worden door de wisselwerking tussen cognitieve vertekeningen. Dit zou therapeutische vooruitgang kunnen ondermijnen. Het onderkennen van de aard van de wisselwerking tussen negatieve vertekeningen in aandacht, interpretatie en geheugen alsook hoe deze adaptieve emotieregulatie kunnen ondermijnen is van belang voor zowel therapeuten als patiënten die met cognitieve technieken aan de slag gaan.

Cognitieve Training

In de afgelopen jaren werden er specifieke methoden ontwikkeld om negatieve vertekeningen in cognitieve processen te remediëren (voor een overzicht zie Koster, Everaert, Bruyneel, & Onraedt, 2013). Deze procedures kunnen negatieve vertekeningen reduceren in onder andere aandacht, interpretatie en geheugen en zijn potentieel klinisch interessant. Inzichten uit onderzoek naar relaties tussen cognitieve vertekeningen hebben implicaties voor de implementatie van dergelijke trainingsmethodieken.

Ten eerste kan een gerichte trainingsaanpak zich baseren op bevindingen die aantonen dat aandachtsvertekeningen een rol spelen bij het interpreteren, opslaan en bewust herinneren van emotionele informatie. Dit suggereert dat wanneer men negatieve vertekeningen in de aandacht kan verminderen, dit kan leiden tot meer positieve en minder negatieve interpretaties die in het geheugen worden opgeslagen alsook meer positieve dan negatieve herinneringen die men uit het geheugen ophaalt. Bijgevolg zou de informatieverwerking minder negatief vertekend zijn waardoor disfunctionele opvattingen over het zelf, anderen en de wereld aangepast kunnen worden. Zo kan kwetsbaarheid voor depressie gereduceerd worden.

Ondanks het potentieel van aandachtstraining bij depressie wijst onderzoek naar de effectiviteit van deze procedures op bescheiden resultaten. Initieel veelbelovende positieve effecten op depressiesymptomen tot drie maanden na de training (Wells & Beavers, 2010) werden niet gerepliceerd bij steekproeven van subklinisch en klinisch depressieve personen (Baert, De Raedt, Schacht, & Koster, 2010; Kruijt, Putman, & Van der Does, 2013). Echter, een studie naar aandachtstraining als een methode ter preventie van terugval bij voorheen depressieve personen vond wel dat training leidde tot minder ernstige depressieve symptomen bij follow-up (Browning, Holmes, Charles, Cowen, & Harmer, 2012). Naast de

beperkte effecten van aandachtstraining op depressiesymptomen, zijn er gemengde bevindingen over de effecten van training op gerelateerde cognitieve processen. Zo hebben studies aangetoond dat het trainen van emotionele vertekeningen in de aandacht niet steeds leidt tot veranderingen in de interpretatie van emotionele informatie (Everaert, Mogoase, David, & Koster, 2014). Anderzijds hebben sommige onderzoekers wel gunstige effecten gevonden van aandachtstraining op het herinneren van emotionele informatie bij personen met verhoogde depressiesymptomen (Blaut et al., 2013). Momenteel zijn de condities voor een optimale implementatie van aandachtstraining bij depressie nog onbekend. Dit vormt een belangrijke uitdaging voor toekomstige studies.

Ten tweede kunnen cognitieve trainingsprocedures gericht worden op de zwakste schakel van de cognitieve vertekeningen als een middel om een toename in depressieve symptomen te voorkomen. Dit houdt in dat men eerst op individueel niveau een grondige assessment dient uit te voeren om negatieve vertekeningen in aandacht, interpretatie en geheugen te identificeren. Vervolgens kan men een de training richten op het meest negatief vertekende proces om op individueel niveau de zwakste schakel bij te sturen (vb.: interpretatie). Dergelijke training kan vervolgens een impact hebben op andere cognitieve vertekeningen (vb.: geheugen). We kunnen speculeren dat een gecombineerde aanpak waarbij negatieve vertekeningen in aandacht en de zwakste schakel worden gereduceerd een beloftevolle methode kan vormen om cognitieve kwetsbaarheid te reduceren en depressiesymptomen te voorkomen.

Toekomstmuziek

De laatste jaren heeft het onderzoek naar relaties tussen cognitieve vertekeningen een grote vooruitgang geboekt. Toch blijven er belangrijke vragen onbeantwoord. Ten eerste is het onduidelijk in welke mate de huidige bevindingen van toepassing zijn op klinisch

depressieve personen. De meeste studies werden uitgevoerd in steekproeven met subklinisch depressieve individuen en slechts enkele studies onderzochten de wisselwerking tussen cognitieve processen in een klinische steekproef. Hoewel overeenkomsten waarschijnlijk lijken, zal verder onderzoek moeten uitwijzen in welke mate de samenhang tussen cognitieve vertekeningen in subklinische steekproeven voorkomen bij klinisch depressieve personen. Ten tweede zullen studies verder relaties tussen cognitieve vertekeningen moeten exploreren. Zo is er weinig bekend over hoe emotionele vertekeningen in het impliciete geheugen beïnvloedt worden door aandachtsvertekeningen tijdens het opslaan van emotionele informatie. Ook is het onduidelijk of impliciete geheugenvertekeningen de aandacht kunnen sturen. Dit vormt een boeiende uitdaging voor verder onderzoek. Tot slot heeft nog maar weinig onderzoek zich toegeleid op de link tussen cognitieve processen en moeilijkheden bij het reguleren van negatieve emoties bij depressie. De besproken relaties tussen cognitieve vertekeningen en emotieregulatie strategieën zijn waarschijnlijk maar studies dienen de veronderstelde verbanden te objectiveren.

Algemeen Besluit

Emotionele vertekeningen in aandacht, interpretatie en geheugen zijn gerelateerde, deels overlappende, cognitieve processen die mede het verloop van depressiesymptomen bepalen. Het huidige onderzoek heeft al enkele aspecten van de complexe wisselwerking tussen deze processen blootgelegd, maar verder onderzoek naar deze processen is nodig om de kennis over deze cognitieve mechanismen uit te breiden. Enkel door het bestuderen van de relaties tussen deze processen kunnen we tot een omvattend begrip komen van cognitieve kwetsbaarheid voor depressie. Op zijn beurt kan dit de verdere ontwikkeling van behandelingsstrategieën inspireren.

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