Depression in early adolescence: The influence of emotion on cognitive control processes

Laura Wante

Supervisor: Prof. Dr. Caroline Braet
Co-supervisor: Prof. Dr. Sven Mueller

A dissertation submitted to Ghent University in partial fulfilment of the requirements for the degree of Doctor of Psychology

Academic year 2016–2017
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Laura Wante, September 2017
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Chapter 1

General Introduction

Depression affects more than 300 million people worldwide and has a major impact on how individuals feel and how they perceive themselves and the world around them (World Health Organisation, 2016). Within psychology, there is a long history of theory and research highlighting the role of negative cognitive schemas and biased information processing in the etiology and maintenance of depressive symptoms (e.g., Beck, 1967; Beck, 1976; Braet, Wante, Van Beveren, & Theuwis, 2015; Dalgleish et al., 2003; Friedmann, Lumley, & Lerman, 2016; Leppanen, 2006). Recently, there has been increasing interest in the role of basic cognitive control processes and the influence of emotion on these processes in depression (Mueller, 2011; Snyder, 2013; Vilgis, Silk, & Vance, 2015). In this context, emerging research in adults suggests that depressed individuals prioritize the processing of negative (irrelevant) emotional information to the detriment of adequate cognitive control performance (for a review see Gotlib & Joormann, 2010; Mueller, 2011). Unfortunately, to date, the interplay between cognitive and emotional processes in adolescents who are currently depressed or at risk for depression has been largely neglected. However, as adolescence is a period of ongoing brain maturation and marked vulnerability for depression (Ernst, Pine, & Hardin, 2006; Hankin et al., 1998), a better understanding of the cognitive and emotional underpinnings of depression in this critical life stage may be of great value for future prevention and early intervention programs.
Depression and Dysphoria in Adolescents

Depression is among the most severe and debilitating mental disorders and is associated with a variety of negative consequences, including impaired peer and family relationships, academic difficulties, and school or work failure (AACAP, 2007; World Health Organisation, 2016). While depression is relatively uncommon during childhood (.03 – 3%), lifetime prevalence increases to over 10% in adolescence and young adulthood (Costello, Erkanli, & Angold, 2006; Kessler & Walters, 1998). Further, data of a large-scale study conducted in 11 European countries indicates that up to 29% of adolescents between 14 and 16 years of age report subclinical depressive symptoms (Balazs, 2013). In addition to these alarming prevalence rates, adolescent depression has been associated with suicidal ideation and a 6-fold increased risk for suicide attempts (Fombonne, Wostear, Cooper, Harrington, & Rutter, 2001b). Moreover, both clinical and subclinical levels of depression have been shown to be highly predictive of chronic and more severe depressive episodes in adulthood (Fombonne, Wostear, Cooper, Harrington, & Rutter, 2001a; Pine, Cohen, Cohen, & Brook, 1999). These estimates emphasize that adolescent depression cannot be ignored or minimized, and that further studies on the underlying mechanisms in this early age group are of major importance.

In past research, the term depression has been used to describe many forms of distress or emotional states. Indeed, adolescent depression is a broad term and may manifest in different forms, ranging from clinically diagnosed depression to milder forms of depressive states that do not fulfill the DSM-5 criteria for MDD (Winokur, 1997). Therefore, it is essential to differentiate between the clinical diagnosis of major depressive disorder (MDD) and subthreshold depression or dysphoria (Gotlib & Joormann, 2010). MDD refers to the clinical form of depression and is characterized by three core symptoms: a depressed or irritable mood, loss of pleasure in daily activities, and decreased interest and motivation. Other peripheral symptoms include psychomotor agitation or retardation, weight loss, decrease or increase in appetite, insomnia or hypersomnia, fatigue, feelings of excessive guilt or worthlessness, impaired ability to concentrate, and suicidal ideation or behavior. According to the American Psychiatric Association’s Diagnostic and Statistical Manual of Mental Disorders - 5th edition (DSM-5; APA, 2013), at least five of these symptoms – including at least one of the core symptoms – have to be present throughout a period of two or more weeks for a person to meet the diagnostic criteria for MDD. Dysphoria refers to a subclinical form of depression and is marked by symptoms
such as a sad mood, blue feelings, hopelessness, and irritability. A dysphoric mood does not necessarily imply the presence of MDD (Kendall, Hollon, Beck, Hammen, & Ingram, 1987), but is considered a prominent and persistent feature of MDD which can be evaluated through self-reported depressive symptomatology. One of the most widely used self-report measures of youth depressive symptoms is the Children’s Depression Inventory (CDI; Kovacs, 1992; Timbremont & Braet, 2002). Given that the CDI is a continuous measure of depressive symptoms, various cut-off scores have been proposed to identify mild (11-12) to moderate (13-14) levels of depression (Kaslow, Rehm, & Siegel, 1984; Kovacs, 1983; Worchel et al., 1990).

While classifying MDD with the help of DSM-5 criteria reflects a *categorical* or diagnostic approach based on assumptions of a disorder model of psychopathology, measuring depressive symptomatology or dysphoria by means of self-report scales reflects a *dimensional* or continuum approach (Hammen & Compas, 1994). The dimensional approach implies that depression is a spectrum disorder, ranging from depressed mood or dysphoria at the one end to the more severe depressive episodes or MDD at the other end (Clark, Beck, & Alford, 1999a). Such an approach is often preferred over a categorical approach to depression given that the manifestation of depression changes throughout development (Weiss & Garber, 2003) and that many individuals do not meet all of the necessary DSM criteria for depression but do suffer from subclinical depressive symptoms (Gillham, Shatte, & Freres, 2000; Rivas-Vazquez, Saffa-Biller, Ruiz, Blais, & Rivas-Vazquez, 2004). Moreover, a dimensional approach fits into the innovative transdiagnostic framework for studying mental problems (Barlow, Allen, & Choate, 2004; Harvey, Watkins, Mansell, & Shafran, 2004). According to this view, psychological disorders should be conceptualized as related conditions that vary along a continuum of psychopathology, instead of categorizing them as separate distinguishable entities. Therefore, the current doctoral dissertation will (mainly) focus on a dimensional conception of depression and assess severity of adolescent depressive symptomatology on a continuous scale.

**Cognitive Approaches to Depression**

The detrimental psychosocial consequences and the high recurrence rates associated with depression (AACAP, 2007; Fombonne et al., 2001b) underscore the importance of identifying risk factors and mechanisms involved in the development of adolescent depression. Within this perspective, cognitive theories of depression provide a
prominent and rich framework for understanding the onset, maintenance, and recurrence of depression. These theories share a focus on the role of negative cognition and maladaptive thinking in depression and make the common assumption that the way in which individuals cognitively process environmental information at least partially determines their risk for developing depression (Dozois & Beck, 2008; Lakdawalla, Hankin, & Mermelstein, 2007).

**Beck’s Cognitive Theory**

One of the most well-known and influential cognitive models of depression is Beck’s cognitive theory (1967, 1976). According to this theory, negative self-referent schemas serve as an important vulnerability factor in the development and persistence of depression (Beck, 1967, 1976). These schemas are conceptualized as stable cognitive structures, which are derived from past experiences and consist of core beliefs concerning the self, the world, and the future. In line with diathesis-stress models of depression (Dozois & Beck, 2008), it is proposed that negative schemas are latent and inactive during a non-depressive state but can be activated by stressful internal or external stimuli. Once activated, the schemas generate distorted negative cognitions and affect information processing in a negatively biased way (Clark, Beck, & Alford, 1999b). To test the proposition that schemas have a major influence on how environmental stimuli and events are processed, substantial research examined information processing biases in depression. Interestingly, considerable evidence supports the existence of depressogenic processing biases (Jacobs, Reinecke, Gollan, & Kane, 2008; Neshat-Doost, Taghavi, Moradi, Yule, & Dalgleish, 1998; Timbremont, Braet, Bosmans, & Van Vlierbergh, 2008) and indicates a negative attentional bias and a better memory for schema-congruent information among adolescents who are currently depressed or at risk for depression (Gibb, Benas, Grassia, & McGeary, 2009; Hankin, Gibb, Abela, & Flory, 2010).

While Beck’s cognitive theory has mainly focused on the negative content of depressive cognition (Beck, 1967, 1976; Clark et al., 1999b), recent cognitive models emphasize an important role of basic underlying cognitive control processes in depression (De Raedt & Koster, 2010; Joormann, Yoon, & Zetsche, 2007; Koster, De Lissnyder, Derakshan, & De Raedt, 2011). In these models, it is postulated that the mere presence and activation of negative schemas does not necessarily lead to recurrent negative thoughts and sustained negative affect that are typically observed in individuals who are currently depressed or at risk for depression. Alternatively, it is stated that vulnerability for depression is mainly determined by the ability to regulate emotions and adaptively deal
with intense negative affect. This emotion regulation ability is, in turn, largely dependent on the ability to cognitively control contents of working memory and the efficient use of executive functions (Joormann et al., 2007; Koster et al., 2011).

**General Cognitive Control Deficits**

In the last decade, it has been suggested that cognitive control impairments play a critical role in the development of depression and underlie repetitive negative thoughts and emotion regulation problems that characterize depressed individuals (Joormann et al., 2007; Koster et al., 2011). *Cognitive control* is an umbrella term for higher-order executive functions that are associated with the prefrontal cortex of the brain and play a crucial role in flexible goal-directed behavior (Banich, 2009; Garon, Bryson, & Smith, 2008). In the literature, many cognitive skills have been referred to as executive functions (EF), such as planning, verbal and visuospatial working memory, response inhibition, and verbal fluency (Snyder, 2013). However, through latent-variable analyses of behavioral measures, three key EF have been identified, which include shifting between tasks or mental sets (*shifting*), inhibiting dominant responses or irrelevant information (*inhibition*), and monitoring and updating the contents of working memory (*updating*) (Diamond, 2013; Miyake et al., 2000). Although these key EF are separable and thus have unique components, it is hypothesized that the active maintenance of goal-relevant information in working memory is a shared element across diverse EF (Miyake & Friedman, 2012; Miyake et al., 2000; Snyder, 2013). *Working memory* (WM) refers to a limited-capacity resource system responsible for brief storage (‘maintenance’) and manipulation of information and is considered important for complex cognitive and behavioral tasks (Baddeley, 2010). EF processes control the access to this system by actively selecting relevant information, inhibiting irrelevant information, and deleting previously relevant information (Hasher & Zacks, 1988).

As mentioned above, adequate cognitive control is required for coordinating different processes which control and modify the content of WM and is needed to pursue goal-directed behavior in a rapidly changing environment. Deficits in cognitive control may thus have a severe impact on adolescents’ daily and academic functioning (Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005; Vilgis et al., 2015). Moreover, such deficits may hinder the flexible use of adaptive emotion regulation strategies in stressful situations and thereby increase the risk for developing depressive symptoms (Joormann & Vanderlind, 2014; Pe, Raes, & Kuppens, 2013; Schmeichel & Tang, 2015). In this context, a growing body of research has investigated cognitive control ability in depressed *adults*.
and showed impairments on specific components of EF, such as inhibition, shifting, verbal fluency, and maintaining, manipulating, or updating the contents of WM (for a review see Ahern & Semkovska, 2017; Snyder, 2013). Moreover, the results of recent meta-analyses suggest that the performance of depressed subjects on EF tasks varies depending on depressive symptomatology, with higher depressive symptom severity predicting greater EF impairments (McDermott & Ebmeier, 2009; Snyder, 2013).

Unfortunately to date, relatively few studies have examined EF ability in adolescents with depression (for a review see Vilgis et al., 2015). Nevertheless, adolescents are a particularly interesting population for studying the underlying cognitive processes of depression. First, it has been shown that adolescent depressive symptoms are predictive of chronic and more severe depressive episodes in adulthood (Klein et al., 1999; Lewinsohn, Clarke, Seeley, & Rohde, 1994). Moreover, as the prefrontal cortex and EF are still developing throughout adolescence (Anderson, 2002; Zelazo & Carlson, 2012) and as adolescence is marked by stressful events (Stroud et al., 2009), cognitive control impairments may have a greater impact on daily life and emotional functioning in adolescents compared to adults. Finally, the identification of cognitive control impairments in adolescents with heightened depressive symptoms may contribute to the understanding of this disorder in youth and may help to identify early signs of depression (Baune, Fuhr, Air, & Hering, 2014; Favre et al., 2009).

**Research evidence in youth samples.** As noted above, studies investigating cognitive control impairments in depressed or dysphoric adolescents are relatively scarce. Moreover, results of these studies have been mixed with only a few studies indicating clear impairments in both global cognitive control ability (e.g., Han et al., 2016; Holler, Kavanaugh, & Cook, 2014; Sommerfeldt et al., 2016) and specific EF (Vilgis et al., 2015). For instance, previous studies on *shifting*, determined by the Wisconsin Card Sorting Test or the Trail-Making-Test, were inconclusive showing either no difference between depressed adolescents and healthy controls (Favre et al., 2009; Han et al., 2016) or reduced shifting ability in the depressed group (Emerson, Mollet, & Harrison, 2005; Holler et al., 2014). Also longitudinal data showed diverging results, with one study by Stange et al. (2016) indicating that set-shifting predicted a shorter time to first onset of MDD in a community sample of adolescents, whereas two other studies failed to find prospective relations between shifting impairments and depressive symptoms in youth (Evans, Kouros, Samanez-Larkin, & Garber, 2016; Han et al., 2016). Further, also studies examining *inhibition* with frequently used tasks such as a go/no go task or an antisaccadic eye
movement task yielded mixed results, with some showing more errors or false alarms in the depressed group (Gunther, Konrad, De Brito, Herpertz-Dahlmann, & Vloet, 2011; Hardin, Schroth, Pine, & Ernst, 2007), while others identified no group differences (Cataldo, Nobile, Lorusso, Battaglia, & Molteni, 2005; Gunther, Holtkamp, Jolles, Herpertz-Dahlmann, & Konrad, 2004). Finally, prior research on WM using visuospatial and verbal learning tasks provided some support for cross-sectional and prospective associations between impaired WM performance and depression in youth (Bloch et al., 2013; Brooks, Iverson, Sherman, & Roberge, 2010; Franklin et al., 2010; Gunther et al., 2004; Han et al., 2016; Matthews, Coghill, & Rhodes, 2008). Yet, empirical evidence is far from being consistent with several studies failing to identify significant differences between depressed and non-depressed adolescents (Constantinidou, Danos, Nelson, & Baker, 2011; Maalouf et al., 2011; Wagner, Alloy, & Abramson, 2015).

The Impact of Emotion on Cognitive Control

Given that depression is typically associated with uncontrollable negative thoughts and emotion regulation difficulties (Joormann & D'Avanzato, 2010), one possibility is that cognitive control ability in depressed individuals is particularly perturbed and thus markedly lower in the context of emotional information (Joormann et al., 2007; Koster et al., 2011; Vilgis et al., 2015). Specifically, it has been suggested that depressed individuals experience particular difficulties inhibiting the processing of irrelevant negative stimuli and disengaging or shifting attention from previously relevant negative stimuli. Such cognitive control impairments in response to negative emotional material are likely to result in broad cognitive impairments (e.g., concentration/memory problems) and may impede the regulation of negative affect (Joormann & D'Avanzato, 2010; Joormann & Vanderlind, 2014). These cognitive and emotional problems may, in turn, result in intrusive negative thoughts and persistent negative affect and thereby increase the risk for depression or the severity of depressive symptoms (Joormann & Gotlib, 2008).

While specific cognitive control deficits when processing negative or schema-congruent information have been clearly demonstrated in adults (Gotlib & Joormann, 2010; Joormann & Tanovic, 2015), the influence of emotional stimuli on cognitive control processes has received scant empirical attention in depressed or dysphoric adolescents (for a review see Mueller, 2011). Yet, research on this age group is of major importance as adolescence is characterized by an imbalance between affective and cognitive development, which significantly increases executive burden and their vulnerability for developing psychopathology and depression in particular (Luciana, 2016; Luciana &
More concretely, this developmental phase is marked by an early maturation of subcortical ‘affective’ regions, such as the amygdala, and a late maturation of prefrontal cortical regions involved in cognitive control processes. This imbalance between affective and cognitive brain systems significantly challenges adolescents’ cognitive control abilities in emotionally laden situations and may generate sustained negative affect and uncontrollable negative thoughts (Ernst et al., 2006; Spear, 2009).

Research evidence in youth samples. To investigate the effect of emotion on cognitive control, prior research has generally added emotional (distracting) information to general cognitive control tasks (Mueller, 2011). In this context, the most commonly used cognitive tasks in pediatric research include the emotional Stroop task and the affective go/no go task to measure inhibition, and the emotional n-back task to measure updating in WM (see Table 1 for an overview). Research with an emotional Stroop task, in which participants had to name the color of the ink of an emotionally valenced word while inhibiting the content of that word, failed to find differences across depressed, anxious, comorbid depressed and anxious, and healthy youth (Dalgleish et al., 2003; Neshat-Doost, Taghavi, Moradi, Yule, & Dalgleish, 1997). In contrast, most studies that used an affective go/no go task, in which participants were presented with a range of emotional stimuli and were asked to respond to certain target stimuli (go trials) and to inhibit their response to other stimuli (no go trials), demonstrated clear differences between depressed and non-depressed adolescents, except for one by Han et al. (2012).

For instance, Ladouceur et al. (2006) indicated faster response times (RTs) to ‘go trials’ with negative emotional faces compared to positive and neutral emotional faces in currently depressed, but not in remitted or healthy adolescents. Moreover, studies using a similar task with verbal stimuli also provided evidence for a negative bias, and indicated lower error rates and faster response times in reaction to negative words compared to positive words in the depressed, but not in the non-depressed group (Kyte, Goodyer, & Sahakian, 2005; Maalouf et al., 2012).

In addition to these studies on the influence of emotion on inhibitory control, a couple of studies have investigated the effect of distracting emotional information on WM performance by using an emotional n-back task. In this task, participants were presented with a series of stimuli and were instructed to indicate whether the current stimulus matches the stimulus presented n-trials before. First, Ladouceur et al. (2005) reported slower RTs in the presence of negative distracting background scenes in depressed and comorbid depressed-anxious adolescents, whereas healthy adolescents responded slower.
in the presence of positive distracting background scenes. Contrary to these results, Tavitian et al. (2014) showed that, when compared to non-depressed adolescents, depressed adolescents’ performance less accurate in the presence of neutral distractor faces, while there was no effect of angry or happy distractor faces. Finally, Lo and Allen (2011) explored depressed youths’ ability to shift between emotional and non-emotional information in WM. In their mental counting paradigm, participants were instructed to mentally count the amount of words in a certain emotional (positive or negative) or non-emotional category (food or household object) and verbally report the number of pictures in each category at the end of each block. In shift trials, the presented word had to be updated to a different category than that of the preceding word, whereas in non-shift trials the presented word belonged to the same category as the previous word. The findings of this study revealed greater shifting difficulties in the depressed compared to the non-depressed group, but only when processing emotional words.

To conclude, despite a growing empirical base in adult populations, cognitive control processes and particularly the effects of emotion on those processes remain understudied in adolescents suffering from depression (Mueller, 2011; Snyder, 2013; Vilgis et al., 2015). Moreover, the scant empirical studies that have focused on depressed adolescents yielded mixed and inconclusive results, leaving it unclear if and how cognitive control deficits in response to emotional information play a role in the pathogenesis of early-onset (adolescent) depression. Finally, as prior studies mainly focused exclusively on adults and adolescents with MDD who are at the ‘extreme’ end of the depression continuum, the interpretation of their findings is limited due to depression severity and recurrent episodes. Instead, the focus on subclinical dysphoric individuals who show elevated levels of depressive symptoms and are at risk for developing clinical depression would enable to gain clearer insight into baseline cognitive processes.
Table 1. Overview of relevant studies on the influence of emotion on cognitive control in adolescents with depression

<table>
<thead>
<tr>
<th>First author</th>
<th>Year</th>
<th>Task</th>
<th>Stimuli</th>
<th>Sample</th>
<th>Main results</th>
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</thead>
<tbody>
<tr>
<td>Han</td>
<td>2012</td>
<td>Emotional go/no go task &amp; Face go/no go task</td>
<td>Emotional go/no go task: happy, fearful, &amp; calm faces&lt;br&gt;Face go/no task: angry, fearful, sad, happy, &amp; neutral faces</td>
<td>MDD vs. HC group&lt;br&gt;&lt;em&gt;M&lt;sub&gt;age&lt;/sub&gt;: 17.39 years&lt;/em&gt;</td>
<td>No significant differences between MDD and HC group&lt;br&gt;Performance variables (RTs) of the Face go/no go task were correlated with depression severity</td>
</tr>
<tr>
<td>Ladouceur</td>
<td>2005</td>
<td>Emotional n-back task</td>
<td>Target stimuli: non-emotional letters&lt;br&gt;Distractor stimuli: negative, neutral, &amp; positive background pictures</td>
<td>MDD, ANX, &amp; CAD vs. HC group&lt;br&gt;&lt;em&gt;M&lt;sub&gt;age&lt;/sub&gt;: 12.69 years&lt;/em&gt;</td>
<td>MDD and CAD groups responded slower on negative emotional backgrounds compared to neutral backgrounds&lt;br&gt;The HC group responded slower on positive backgrounds</td>
</tr>
<tr>
<td>Ladouceur</td>
<td>2006</td>
<td>Emotional go/no go task</td>
<td>Angry, fearful, sad, happy, &amp; neutral adult faces</td>
<td>MDD &amp; ANX, vs. HC group&lt;br&gt;&lt;em&gt;M&lt;sub&gt;age&lt;/sub&gt;: 12.52 years&lt;/em&gt;</td>
<td>Sad facial expressions influenced the performance of the MDD group in the moderate probability condition (faster RTs)&lt;br&gt;The angry facial expressions influenced performance of the ANX group in the low probability condition (slower RTs)</td>
</tr>
<tr>
<td>Tavitian</td>
<td>2014</td>
<td>Emotional Face n-back task</td>
<td>Target stimuli: non-emotional letters&lt;br&gt;Distractor stimuli: Neutral, happy, &amp; angry distractor faces</td>
<td>MDD vs. HC group&lt;br&gt;&lt;em&gt;M&lt;sub&gt;age&lt;/sub&gt;: 15.02 years&lt;/em&gt;</td>
<td>Neutral faces negatively affected performance (higher error rates) of the MDD group</td>
</tr>
</tbody>
</table>

*Note. MDD = Major Depressive Disorder; ANX = anxiety; CAD = comorbid MDD-anxiety; HC = healthy control; RT = response time.*
Table 1 (continued). Overview of relevant studies on the influence of emotion on cognitive control in adolescents with depression

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<tr>
<th>First author</th>
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<th>Task</th>
<th>Stimuli</th>
<th>Sample characteristics</th>
<th>Main results</th>
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<tr>
<td>Dalgleish</td>
<td>2003</td>
<td>Stroop task &amp; Dot probe task</td>
<td>Depression-related, threat-related, positive, &amp; neutral words</td>
<td>MDD &amp; ANX vs. HC group</td>
<td>Dot probe task: general attentional bias towards negatively valenced stimuli in MDD group + a greater attentional bias towards threat-related stimuli relative to depression-related stimuli in ANX group. Stroop task: no clear bias.</td>
</tr>
<tr>
<td>Kyte</td>
<td>2005</td>
<td>Affective go/ no go</td>
<td>Happy &amp; sad words</td>
<td>MDD vs. HC group</td>
<td>MDD group made more errors on happy target words and fewer errors on sad target words.</td>
</tr>
<tr>
<td>Lo</td>
<td>2011</td>
<td>Mental Counting Paradigm</td>
<td>Positive, negative, &amp; neutral words</td>
<td>MDD vs. HC group</td>
<td>MDD group showed lower accuracy rates in response to both emotional and neutral words. MDD group showed slower RTs when processing emotional words.</td>
</tr>
<tr>
<td>Maalouf</td>
<td>2012</td>
<td>Affective go/ no go</td>
<td>Happy &amp; sad words</td>
<td>MDD (current/past) vs. HC group</td>
<td>Current MDD group responded faster when the valence of the target stimulus shifted to negative as compared to positive shifts.</td>
</tr>
<tr>
<td>Neshat-Doost</td>
<td>1997</td>
<td>Stroop task</td>
<td>Depression-related, threat-related, trauma-related, happy, &amp; neutral words</td>
<td>MDD &amp; CAD vs. healthy group</td>
<td>The HC group were generally faster in naming the colors of the words. Performance between the groups did not differ for different categories of words.</td>
</tr>
</tbody>
</table>

*Note.* MDD = Major Depressive Disorder; ANX = anxiety; CAD = comorbid MDD-anxiety; HC = healthy control; RT = response time.
Research Objectives and Overview of the Chapters

The major aim of the current doctoral dissertation was to investigate the influence of emotion on cognitive control ability, with a particular focus on three key EF processes: (updating in) WM, inhibition, and shifting. Despite the growing body of evidence on cognitive control impairments in adults diagnosed with MDD, little research has been conducted in younger age groups with (sub)clinical depressive symptoms. Moreover, results of the few studies on general cognitive control deficits in depressed or dysphoric adolescents were mixed with a trend toward null findings, leading to the central idea that cognitive control may be particularly hampered in the context of emotional information. Since cognitive control is an umbrella term for different EF processes, four different experimental tasks were used to operationalize this construct.

The deliberate choice to focus on dysphoric adolescents in this dissertation is based on the following arguments. First, the developmental phase of adolescence is characterized by significant stress and turmoil and represents a particularly vulnerable period for the development of depressive symptoms (Calkins, 2010; Dahl, 2004). Further, suffering from subclinical depressive symptoms in adolescence is an important predictor of developing (more severe) depressive episodes in adulthood (Pine et al., 1999; Pine, Cohen, Gurley, Brook, & Ma, 1998). Finally, cognitive control ability is stated to play a key role in the etiology of depression, which makes it highly relevant to study EF processes in dysphoric youth before a full-blown depression occurs.

In Chapter 2 our goal was to examine whether impairments in everyday EF lead to depressive symptoms through emotion regulation ability, which is a central assumption of the current dissertation. A cross-sectional study was conducted with 579 adolescents (age 10 to 16) and one of their parents who completed questionnaires measuring EF, adaptive and maladaptive emotion regulation strategies, and depressive symptoms. We expected that EF deficits would be associated with a greater use of maladaptive emotion regulation strategies and a lower use of adaptive emotion regulation strategies, which would in turn lead to higher levels of depressive symptoms.

In the subsequent chapters, we aimed at exploring which specific EF impairments underlie emotion dysregulation in depressed adolescents. Given that the questionnaire design of Chapter 2 only provides a rough measure of everyday EF, we then examined the effect of emotional information on specific EF processes through objective performance-based measures in an experimental design.
In Chapters 3 and 4, we focused on the effect of emotional information on WM performance since a flexible WM in the context of emotional information is hypothesized to play a crucial role in one’s ability to regulate emotions (Joormann, Yoon, & Siemer, 2010; Schmeichel & Tang, 2015). In Chapter 3, we compared the performance of depressed (n = 27) and non-depressed adolescents (n = 49) on an emotional n-back task, in which they were presented with a series of pictures of adult faces and were asked to indicate whether the current stimulus matches the stimulus presented n-trials before. As the influence of emotional stimuli on cognitive control processes is assumed to depend on task-relevance of the stimuli (Kanske, 2012), the n-back task consisted of an emotion-relevant condition, in which attention had to be directed towards the emotional expression of the face, and an emotional irrelevant condition, in which attention had to be focused on the gender of the face. Chapter 4 aimed to replicate and extend the results of Chapter 3 in dysphoric adolescents and determine whether the same cognitive mechanisms operate in youth at risk for developing clinical depression. Contrary to the study discussed in Chapter 3 and to the majority of previous work that relied on manual reaction time measures, this study employed a saccadic eye movement task providing a direct and precise measure of visuospatial WM. In this task, dysphoric (n = 25) and non-dysphoric participants (n = 40) had to maintain fixation to a central point while remembering the location of target stimuli that were briefly presented in the periphery. Importantly, the target stimuli were colored rectangles, which were overlaid with irrelevant affective stimuli (i.e., emotional adult faces).

In Chapter 5 and Chapter 6, our goal was to explore the effect of emotion on two other key EF: inhibition and shifting between mental sets. Unlike Chapters 3 and 4, which used emotional adult faces, the behavioral tasks to measure cognitive control in these studies included emotional child faces. This shift from adult to child faces was based on the argument that angry child faces may activate depressogenic schemas of peer rejection (Gotlib, Krasnoperova, Yue, & Joormann, 2004; Hames, Hagan, & Joine, 2013; Mueller, De Rubeis, Lange, Pawelzik, & Sutterlin, 2016) and may thus be more relevant to dysphoric adolescents than adult faces. In Chapter 5, a Negative Affective Priming task was used to measure the process of interference and subsequent inhibition of emotional information in dysphoric adolescents. In this multi-stimulus task, dysphoric (n = 21) and non-dysphoric adolescents (n = 28) were asked to respond to a target stimulus, while ignoring a simultaneously presented emotional distractor stimulus. The presentation of a separate distractor and target stimulus improves the design of the studies discussed in
Chapters 3 and 4, in which relevant and irrelevant information were displayed within the same stimulus presentation. In **Chapter 6**, we aimed to take another step forward by exploring *internal* cognitive control instead of external cognitive control processes and the ability to shift between mental sets in WM in particular. Given that impaired internal cognitive control is strongly associated with recurrent negative thoughts or rumination in depressed adults (Demeyer, De Lissnyder, Koster, & De Raedt, 2012; Koster, De Lissnyder, & De Raedt, 2013), this process may be of specific relevance in the development of depressive symptoms. To this aim, we used the Internal Shifting Task, in which dysphoric \((n = 20)\) and non-dysphoric participants \((n = 34)\) were presented with pictures of faces and were instructed to mentally count the amount of negative and neutral (emotional condition) or male and female (non-emotional condition) faces.

Finally, **Chapter 7** provides an integrated overview and general discussion of the main findings of this thesis. Additionally, methodological considerations, clinical implications, limitations, and avenues for future research are discussed.
References


Abstract

Past research results suggest that executive functioning (EF) impairment represents an important vulnerability factor in depression. Little research, however, has examined mechanisms underlying this association. The current study investigates the associations between EF impairment, emotion regulation (ER) strategies, and depressive symptoms in a sample of 579 adolescents (320 females, mean age = 12.06 years). Parents reported on adolescents’ EF and general psychopathology, and adolescents self-reported ER strategies and depressive symptoms. The results indicate that greater EF impairment is associated with more depressive symptoms. Youth with greater EF impairment reported more maladaptive ER and less adaptive ER, and maladaptive and adaptive ER strategies jointly mediated the association between EF impairment and depressive symptoms. The results highlight an important role of both maladaptive and adaptive ER in explaining the relationship between EF and depressive symptoms and suggest that clinical interventions targeting ER skills may provide one strategy for the prevention and treatment of depression. Further longitudinal research is needed to replicate these results and evaluate the causality of the relations.

Introduction

Depression in adolescents is a severe and often recurrent illness associated with impaired psychosocial functioning and increased mortality (AACAP, 2007). With a low prevalence during childhood, prevalence of clinically significant depression is over 10% in adolescence (Kessler & Walters, 1998). In addition, epidemiological data from 11 European countries show that up to 29% of youth report subclinical depressive symptoms during adolescence (Balazs, 2013). Since depression and depressive symptoms may impede adolescents’ social, emotional, and cognitive development (Rothon et al., 2009), and are predictive of subsequent and more serious depressive episodes (Lewinsohn, Clarke, Seeley, & Rohde, 1994; Pine, Cohen, Cohen, & Brook, 1999), more research on vulnerability factors increasing the risk for depression in adolescence is urgently needed.

A growing body of research among adults suggests that impairments in executive functions (EF), such as inhibition and shifting, are an important vulnerability factor for depression (e.g., Joormann & D'Avanzato, 2010; Wagner, Doering, Helmreich, Lieb, & Tadic, 2012). However, the mechanisms mediating this association remain poorly understood. It has been proposed that one mechanism linking EF with depressive symptoms is emotion regulation (ER; Demeyer, De Lissnyder, Koster, & De Raedt, 2012; Joormann & D'Avanzato, 2010). Specifically, poor EF may lead to a greater use of maladaptive ER strategies, such as rumination, and may interfere with the use of adaptive ER strategies, such as cognitive reappraisal (Joormann & D'Avanzato, 2010).

Studies on EF and its association with ER and depressive symptoms in adolescents have been fewer in number and have yielded mixed results (Baune, Fuhr, Air, & Hering, 2014; Vilgis, Silk, & Vance, 2015). Therefore, the present study aims to extend previous work by examining whether EF is related to depressive symptoms in adolescents and whether this relationship is mediated by adolescents’ adaptive and maladaptive ER strategies.

Executive Functioning and Depressive Symptoms

EF refers to a set of higher order cognitive processes that are associated with the prefrontal cortex of the brain and underlie goal-directed behaviors, such as working memory, planning, set shifting, and inhibitory control (Garon, Bryson, & Smith, 2008; Miyake et al., 2000). EF is essential to efficiently update contents of working memory, which is considered to be a limited-capacity system that stores information for brief periods of time in the service of cognitive processes (e.g., Baddeley, 2003; Friedman &
Miyake, 2004; Hasher, Zacks, & May, 1999). Specifically, executive processes control the access to working memory by actively selecting relevant information, inhibiting irrelevant information, and deleting previously relevant information (Hasher & Zacks, 1988).

It is suggested that, specifically during information processing, impaired executive control over negative information may lead to increased negative cognitions and prolonged negative affect, which in turn increase the risk for depression (Joormann, Yoon, & Zetsche, 2007; Koster, De Lissnyder, Derakshan, & De Raedt, 2011). Recent neuropsychological studies in clinically depressed and dysphoric adults have already provided considerable evidence that impairments in multiple aspects of EF are indeed associated with the development and recurrence of depression. Specifically, compared to healthy controls, depressed and dysphoric participants showed significant deficits on specific components of EF, such as inhibition, shifting, and verbal fluency (for a review see Snyder, 2013). Relatively few studies, however, have investigated EF in depressed or dysphoric adolescents and results of these studies have been mixed (Baune et al., 2014; Vilgis et al., 2015). Nevertheless, a number of recent studies in depressed or dysphoric adolescents have provided evidence for impairments on both global EF (e.g., Han et al., 2016; Holler, Kavanaugh, & Cook, 2014) and specific EF components, such as working memory (e.g., Bloch et al., 2013; Evans, Kouros, Samanez-Larkin, & Garber, 2016), cognitive flexibility (e.g., Evans et al., 2016; Holler et al., 2014), and inhibition (e.g., Colich, Foland-Ross, Eggleston, Singh, & Gotlib, 2016; Wante, Mueller, Demeyer, De Raedt, & Braet, 2015).

Additional research investigating underlying cognitive processes in adolescents is needed for several reasons. First, as the prefrontal cortex and EF are still developing through (early) adolescence (Anderson, 2002; Zelazo & Carlson, 2012) and as adolescence is marked by stressful events and increased stress reactivity (Stroud et al., 2009), EF impairments may have a greater impact on cognitive and emotional functioning in adolescents compared to adults. Moreover, emerging evidence indicates that EF is still malleable in adolescence and can be improved by training and practice (Jaeggi, Buschkuehl, Jonides, & Shah, 2011; Zelazo & Carlson, 2012; Zinke, Einert, Pfennig, & Kliegel, 2012). Furthermore, it has been shown that adolescent depressive symptoms are predictive for more chronic and severe depressive episodes and are associated with significant psychosocial impairment compared to adult onset depression (Klein et al., 1999; Lewinsohn, Rohde, Seeley, Klein, & Gotlib, 2000). Finally, the identification of EF impairments in adolescents with depressive symptoms may improve cognitive theories concerning the development of depression, may contribute to the understanding of this
disorder among youth, and may help in identifying early signs of depression (Baune et al., 2014; Favre et al., 2009).

**Emotion Regulation as a Mediator of the Relationship between Executive Functioning and Depressive Symptoms**

Recently, it has been stated that inadequate ER may be one pathway through which EF influences the development of depressive symptoms (e.g., Demeyer et al., 2012; Joormann, 2010). ER can be described as “processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions” (Gross, 1998b, p. 275). Specific ER strategies are considered adaptive or maladaptive depending on their effects on affect and behavior and their association with psychopathology in the long term (for a review see Aldao, Nolen-Hoeksema, & Schweizer, 2010). On the one hand, it is suggested that adaptive ER strategies - such as cognitive reappraisal, acceptance, and problem solving - reduce negative affect and exert protective effects against the development of psychopathology (Aldao & Nolen-Hoeksema, 2012; Gross & John, 2003). On the other hand, maladaptive ER strategies - such as rumination, avoidance, and suppression - are stated to be less effective in reducing negative emotion over the long term and have consistently been seen as risk factors for the development of a wide range of mental disorders (Aldao et al., 2010; Gross, 1998a; John & Gross, 2004).

Not surprisingly, emerging research supports the premise that impaired ER predicts depressive symptoms among adolescents. Findings suggest that an increased use of maladaptive ER strategies (e.g., rumination, avoidance) and a decreased use of adaptive ER strategies (e.g., cognitive reappraisal, problem solving) predicts higher levels of depressive symptoms both concurrently and prospectively (Cracco, Van Durme, & Braet, 2015; Garber, Braafsladt, & Weiss, 1995; Mezulis, Priess, & Hyde, 2011; Silk, Steinberg, & Morris, 2003; Verstraeten, Vasey, Raes, & Bijeetebier, 2009; Yap et al., 2011; Zhao & Zhao, 2015).

Since EF is required for coordinating different processes which control and modify the content of working memory, it is likely to affect one’s ability to regulate emotions (Eisenberg, Champion, & Ma, 2004; Joormann, Yoon, & Siemer, 2010; Schmeichel & Tang, 2015). Specifically, difficulties inhibiting mood-congruent information and updating the content of working memory with mood-incongruent information may impede one’s ability to refocus attention (e.g., thinking about positive and pleasant issues) or to reinterpret emotion-eliciting situations to repair mood (e.g., cognitive reappraisal) (Joormann & D'Avanzato, 2010; Kovacs, Joormann, & Gotlib, 2008). Moreover, results
of neuroanatomical studies suggest that studying the association between EF and ER may be particularly relevant in adolescents. Specifically, it has been shown that part of the increased vulnerability for depression in adolescents can be found in the “ongoing” brain development that is characterized by an imbalance between an early maturation of subcortical regions, such as the amygdala, that regulate emotional functioning in the brain and a late maturation of prefrontal cortical regions involved in EF (Ernst, Pine, & Hardin, 2006; Price & Drevets, 2010).

At present there is little research linking EF impairments with the use of ER strategies among children and adolescents (e.g., Carlson & Wang, 2007; Hilt, Leitzke, & Pollak, 2014; Hilt & Pollak, 2013), although this relationship has been well established among adults. Interestingly, extensive research among adults has already demonstrated that EF deficits are related to the use of specific maladaptive ER strategies, such as rumination (e.g., Davis & Nolen-Hoeksema, 2000; Joormann, Dkane, & Gotlib, 2006; Joormann & Gotfib, 2008). A recent study of Demeyer et al. (2012) conducted on remitted depressed adults provides evidence for the mediating role of rumination in the influence of impaired cognitive control on depressive symptoms over time. Current research is further limited as only a few studies have investigated the association among EF and the use of adaptive ER strategies. This is nevertheless important since the use of adaptive ER strategies is essential for maintaining or restoring mental health (Berking & Whitley, 2014). In this light, one study by Joormann and D’Avanzato (2010) has shown that impaired cognitive control is related to less use of cognitive reappraisal in both healthy and depressed adults. Additionally, while most studies are focusing on specific ER strategies, it might be interesting to study the range of ER strategies an individual has at his or her disposal (Yap et al., 2011). Specifically, it can be assumed that a wider range of available adaptive ER strategies offers the individual a greater flexibility to use different strategies when needed, while a wider range of maladaptive ER strategies might reflect one’s general emotion dysregulation. Accordingly, Yap et al. (2011) found that overall, self-reported adaptive and maladaptive ER strategies partially mediated the association between negative emotionality and depressive symptoms in early adolescents. However, these results are preliminary and further research on this topic is needed.

The Current Study

The current study extends previous research by examining the associations between EF, adaptive and maladaptive ER strategies, and depressive symptoms in a sample of adolescents. Given the high risk of depression and the ongoing brain
development in adolescents (Ernst et al., 2006), it is highly relevant to study these processes in this age group (Dahl, 2004; Twenge & Nolen-Hoeksema, 2002). Although performance-based measures are often used to attain an adequate and objective measure of specific EF components in a controlled laboratory setting (for a review, see Vilgis et al., 2015), most of these neuropsychological EF tasks lack ecological validity. Since the aim in this study is to have a global measure of adolescents’ everyday EF, it was decided that EF impairment would be measured using parent reports on the standardized Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000). The BRIEF is a behavioral rating scale that was developed to measure adolescents’ everyday EF within the home or school environment (Gioia et al., 2000). Given that performance-based measures assess specific EF components on a neuropsychological level and behavior rating scales such as the BRIEF measure global EF on a behavioral level (Pennington, 2002), both approaches are considered valuable and do not exclude one another (Barkley & Fischer, 2011; Gioia, Isquith, Kenworthy, & Barton, 2002). Recent research results in adolescents with attention-deficit/hyperactivity disorder (ADHD) provided support for moderate convergence between neuropsychological performance-based measures of EF and behavioral ratings with the BRIEF (Toplak, Connors, Shuster, Knezevic, & Parks, 2008). Moreover, a number of studies already indicated an important association between EF impairment as measured with the BRIEF and depressive or internalizing symptoms in healthy, at-risk, and clinically referred youth (Evans et al., 2016; Kelly et al., 2012; White, Jarrett, & Ollendick, 2013). In the current study, it was hypothesized that impaired EF would be associated with higher depressive symptoms. In addition, it was hypothesized that an increased use of maladaptive ER strategies and a decreased use of adaptive ER strategies would be associated with higher depressive symptoms. Finally, it was hypothesized that more maladaptive and less adaptive ER strategies would mediate the relationship between impaired EF and depressive symptoms.

**Methods**

**Participants**

The participants consist of 579 Dutch-speaking adolescents between 10 and 16 years of age (55% female; mean age = 12.06, SD = 1.45) and one parent of each adolescent. All participants were of Caucasian ethnicity.
Procedure

In order to obtain a youth sample with a broad range of depressive symptoms, healthy (434 or 75%), at-risk (93 or 16%), and referred adolescents (52 or 9%) were included in the study sample. Healthy participants were recruited through advertising in schools, while at-risk participants were selected from a screening sample of 1868 youngsters who were participating in a larger school-based study. Adolescents were selected from the screening sample if their scores were above the subclinical cutoff score of 11 on the Children’s Depression Inventory (Kovacs, 1992; Mattison, Handford, Kales, & Goodman, 1990; Timbremont & Braet, 2002). The referred adolescents were recruited from an inpatient and an outpatient clinical center and were all referred for treatment of emotional (internalizing) problems. All prospective participants received an information letter explaining the aim of the study and a request to participate. Adolescents signed informed assent while legal guardians signed informed consent. After agreement to participate had been obtained, each adolescent and one of his or her parents was asked to fill out a battery of questionnaires at home or at the university. The research protocol was approved by the ethics committee of the university hospital.

Measures

Depressive symptoms. A Dutch version of the Children’s Depression Inventory (CDI; Kovacs, 1992; Dutch version by Timbremont & Braet, 2002) was used to assess depressive symptoms. The CDI is a self-report questionnaire derived from the Beck Depression Inventory (BDI; Beck, Ward, Mendelsohn, Mock, & Erbaugh, 1961) that is used in children and adolescents aged 7 to 17 years. It consists of 27 items, which assess cognitive, affective, and behavioral symptoms of depression. Each item has three response options which vary in severity (e.g., “I do most things wrong”, “I do many things wrong”, “I do everything wrong”). Test takers are asked to select the statement that best describes how they have been feeling during the past two weeks. A total depression score consists of the sum of all individual items. CDI showed good psychometric qualities in terms of internal consistency and test-retest reliability in non-clinical samples (Craighead, Smucker, Craighead, & Ilardi, 1998; Timbremont & Braet, 2002). The Cronbach’s alpha in the present study was .84.

Adaptive and maladaptive emotion regulation. The Fragebogen zur Erhebung der Emotionsregulation bei Kindern und Jugendlichen was used to assess 15 ER strategies in response to anxiety, sadness, and anger (FEEL-KJ; Cracco et al., 2015). The FEEL-KJ
is a 90-item self-report measure and is designed for 9- to 19-year-olds. The questionnaire items were constructed bottom up based on qualitative interviews with 4- to 16-year-olds. In the final version, the authors selected 15 strategies including a couple of well-known adaptive ER strategies, such as cognitive reappraisal, acceptance, and problem solving, and a couple of well-known maladaptive ER strategies, such as rumination and withdrawal (see Aldao et al., 2010). Every strategy is measured with two items for each of the three emotions and the items are rated on a five-point scale, ranging from never to almost always. Based on the results of exploratory and confirmatory factor analyses, the different ER strategies can be divided into two global categories: Adaptive and Maladaptive. The Adaptive ER strategies consist of Cognitive Problem-Solving, Problem-Solving, Acceptance, Forgetting, Distraction, Revaluation, and Humor Enhancement. The maladaptive ER strategies consist of Giving up, Withdrawal, Aggressive actions, Self-Devaluation, and Rumination. The three remaining strategies (Expression, Social Support, and Emotional Control) cannot be classified as specifically adaptive or maladaptive and therefore are not used in the current study. The FEEL-KJ has been shown to have good psychometric qualities in terms of reliability and validity (Cracco et al., 2015; Grob & Smolenski, 2005). In the current study, internal consistency for adaptive and maladaptive ER strategies was good, with a Cronbach’s alphas of .94 and .85, respectively.

Executive functioning. A Dutch parent-rated version of the BRIEF was used to measure children’s EF (Gioia et al., 2000). The 75-item BRIEF assesses two overall indexes of EF: Behavior Regulation Factor and Metacognition Index. The overall indexes are assessed by eight specific subscales: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan-Organize, Organization of Materials, and Monitor. In addition, a total score reflecting overall EF can be computed by summing up the index scores. Higher scores reflect more difficulties in behavior regulation and metacognition and thus represent more EF impairment. According to the BRIEF manual (Gioia et al., 2000), t-scores of 1.5 standard deviations (SDs) above the normative mean (t-scores > 65) indicate severe or clinical EF impairment, while t-scores of at least one SD above the mean (t-scores of 60 to 65) reflect moderate or subclinical EF impairment. Evaluation of the psychometric properties of the BRIEF has revealed good internal consistency and test-retest reliability (Smidts & Huizinga, 2009), while a study by Gioia, Isquith, Retzlaff, and Espy (2002) provides evidence for the validity of the BRIEF as a multidimensional measure of EF. The Cronbach’s alpha for the current study was .96 for the Total Problem Scale.
**General psychopathology.** The Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001; Dutch version by Verhulst, Ende, & Koot, 1996) is a parent-report questionnaire measuring emotional and behavioral problems in 6- to 18-year-olds. It consists of 113 items which are scored on a three-point scale and represent eight syndromes of psychopathology. The scores on these syndrome scales can be summed up to calculate a dimensional score for internalizing problems, externalizing problems, and total problems. Additionally, Diagnostic and Statistical Manual of Mental Disorders (DSM)-oriented scales can be computed measuring Affective Problems, Anxiety Problems, Somatic Problems, ADHD Problems, Oppositional Problems, and Conduct Problems. These scales appear to be a valid and reliable screening measure for *DSM-IV* disorders (Achenbach & Rescorla, 2001; Nakamura, Ebesutani, Bernstein, & Chorpita, 2009). In this study, the DSM-oriented scale for Anxiety Problems and ADHD Problems were used. Internal consistency for the CBCL Anxiety subscale and the CBCL ADHD subscale is good with a Cronbach’s alphas of .71 and .81, respectively.

**Data Analyses**

**Missing values.** The preliminary analyses of the raw data suggest that the extent of missing data ranged between 2.4 and 8.1% per variable. Comparison of means and covariances of all questionnaire variables using Little’s (1988) Missing Completely At Random (MCAR) test revealed a normed chi-square of 1.07, *p* = .30, indicating that the data were likely missing at random across all questionnaires (Bollen, 1989). As a consequence, missing values can be estimated and it was decided to estimate them following the expectation maximization (EM) algorithm available in SPSS (Schafer, 1997).

**Data analytic plan.** Descriptive analyses were conducted on both the entire sample and by status on EF impairment. Participants were divided into EF impairment groups based on their *t*-scores on the BRIEF: (1) Low (*t* < 60, *n* = 413) (2) Moderate (*t* = 60-65, *n* = 102), and (3) Severe (*t* > 65, *n* = 64). Depressive symptoms and maladaptive and adaptive ER strategies were compared among the groups by analysis of variance (ANOVA) models with the Tukey-Kramer test for multiple comparisons. Scores on depressive symptoms, maladaptive, and adaptive ER strategies were square-root transformed prior to the ANOVA to bring skewness and kurtosis into acceptable ranges.

The SPSS PROCESS macro command set developed by Preacher and Hayes (2008; Model 4) was used to test the mediation model in which both adaptive and maladaptive ER strategies are hypothesized to mediate the relationship between EF
impairment and depressive symptoms. A mediation model suggests that the relationship between the independent variable (EF impairment) and the dependent variable (depressive symptoms) is partially or completely accounted for by some mediating variable(s) (ER strategies). For mediation to occur, significant associations should be found between EF impairment and depressive symptoms (c-path; see Figure 1). Second, significant associations should be found between EF and both adaptive and maladaptive ER strategies (a-path) and between both adaptive and maladaptive ER strategies and depressive symptoms after controlling for EF impairment (b-path). Finally, the indirect path between EF impairment and depressive symptoms through both adaptive and maladaptive ER strategies (ab-path) should be significant. When adding this indirect path to the model, the direct effect of EF on depressive symptoms (c’ path) should no longer be significant (complete mediation) or should be lower compared with the total direct effect (partial mediation). The nonparametric procedure developed by Preacher and Hayes (2008) employs a bias-corrected bootstrap method with 5000 resamples to derive the 95% confidence intervals for the indirect effects. Advantages of this bootstrapping procedure compared to previous approaches, such as the Baron and Kenny method (Baron & Kenny, 1986), are that it does not impose distributional assumptions and it takes into account the correlations between mediators and the effect of control variables. Consequently, pure mediation effects are reported independent of the influence of other mediators or control variables (Preacher & Hayes, 2008). Alpha was set at $p = 0.05$, two-tailed.

**Results**

**Descriptive Statistics**

Table 1 displays descriptive statistics and correlations between impaired EF, depressive symptoms, and ER strategies in the study sample ($n = 579$). As expected, significant correlations were found between EF impairment and depressive symptoms, EF impairment and ER strategies, and ER strategies and depressive symptoms.
Table 1  
**Variable correlations, means, and SDs**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. EF impairment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Depressive symptoms</td>
<td>.33***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.40</td>
<td>5.82</td>
</tr>
<tr>
<td>3. Maladaptive ER</td>
<td>.13**</td>
<td>.40***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>74.09</td>
<td>16.21</td>
</tr>
<tr>
<td>4. Adaptive ER</td>
<td>-.10*</td>
<td>-.30***</td>
<td>.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>134.66</td>
<td>25.35</td>
</tr>
<tr>
<td>5. Anxiety symptoms</td>
<td>.46***</td>
<td>.22***</td>
<td>.12**</td>
<td>-.06</td>
<td></td>
<td></td>
<td></td>
<td>1.93</td>
<td>2.03</td>
</tr>
<tr>
<td>6. ADHD symptoms</td>
<td>.71***</td>
<td>.24***</td>
<td>.01</td>
<td>-.05</td>
<td>.35***</td>
<td></td>
<td></td>
<td>3.62</td>
<td>2.91</td>
</tr>
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<td>7. Age</td>
<td>.02</td>
<td>.19***</td>
<td>.11*</td>
<td>-.05</td>
<td>.04</td>
<td>.00</td>
<td></td>
<td>12.06</td>
<td>1.45</td>
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<td>8. Gender</td>
<td>-.16***</td>
<td>.07</td>
<td>.11**</td>
<td>-.04</td>
<td>.07</td>
<td>-.18***</td>
<td>.10*</td>
<td></td>
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</tbody>
</table>

*Note.* \(^*p < .05, **p < .01, ***p < .001. ADHD = attention-deficit/hyperactivity disorder; EF = Executive Functioning; ER = Emotion Regulation.*
It was also examined whether depressive symptoms and/or ER strategies vary across the EF groups. The findings are that 71% of youth are in the normal range for EF and displayed low EF impairments, while 18% displayed moderate EF impairments and 11% displayed severe EF impairments based upon standardized cutoff scores on the parent-reported BRIEF (see Table 2). With regard to depressive symptoms, the Severe group reported higher depressive symptoms than the Moderate ($p = .008$, Cohen’s $d = .46$) and Low ($p < .001$, Cohen’s $d = .73$) groups. The results also indicate significant differences between the Moderate and Low groups ($p = .03$, Cohen’s $d = .28$). With respect to maladaptive ER strategies, no difference emerged between the Severe and Moderate groups ($p = .994$, Cohen’s $d = .01$) and the Low Group ($p = .349$, Cohen’s $d = .19$) or between the Moderate and Low groups ($p = .274$, Cohen’s $d = .18$). As for adaptive ER strategies, the Severe group reported a lower use of adaptive ER strategies in comparison to the Moderate group ($p = .04$, Cohen’s $d = -.35$) and a marginally significant lower use of adaptive ER strategies compared to the Low group ($p = .07$, Cohen’s $d = -.30$). The results indicate no significant differences between the Moderate and the Low groups in adaptive ER strategies ($p = .687$, Cohen’s $d = .07$).

**Table 2**

ANOVA results of depressive symptoms (CDI), maladaptive ER, and adaptive ER of the low, moderate, and severe EF impairment groups based on the BRIEF scores

<table>
<thead>
<tr>
<th></th>
<th>Low (L) ($n = 413$)</th>
<th>Moderate (M) ($n = 102$)</th>
<th>Severe (S) ($n = 64$)</th>
<th>$F$</th>
<th>Post-hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depressive symptoms</td>
<td>7.62 (5.28)</td>
<td>9.15 (5.74)</td>
<td>12.25 (7.47)</td>
<td>17.41***</td>
<td>S &gt; M &gt; L</td>
</tr>
<tr>
<td>Maladaptive ER</td>
<td>73.23 (15.58)</td>
<td>76.27 (18.86)</td>
<td>76.15 (15.40)</td>
<td>1.84</td>
<td>S = M = L</td>
</tr>
<tr>
<td>Adaptive ER</td>
<td>135.22 (24.36)</td>
<td>137.02 (27.17)</td>
<td>127.28 (27.69)</td>
<td>3.16*</td>
<td>S &lt; M=L</td>
</tr>
</tbody>
</table>

*Note. *$p<.05$; ***$p<.001$. ANOVA = analysis of variance; BRIEF = Behavior Rating Inventory of Executive Function; EF = Executive Functioning; ER = Emotion Regulation. SDs are in parentheses.

**Executive Functioning, Emotion Regulation, and Depressive symptoms**

The current study investigated a mediation model in which both adaptive and maladaptive ER strategies were hypothesized to mediate the association between EF impairment and depressive symptoms (Figure 1). Since depressive symptoms are often
Is EF impairment associated with depressive symptoms? The first hypothesis examined is EF impairment being related to greater depressive symptoms. As hypothesized, results show a significant association between EF impairment and depressive symptoms (c-path; $\beta = .32$, $t = 5.50$, $p < .001$).

Is EF impairment associated with ER strategies? Next, the hypothesis that impaired EF is related to a greater use of maladaptive ER strategies and less use of adaptive ER strategies was examined (a-path). The results confirm a significant association between EF impairment and maladaptive ER strategies ($\beta = .22$, $t = 3.62$, $p < .001$) and between EF impairment and adaptive ER strategies ($\beta = -.13$, $t = -2.16$, $p = .031$).

Do ER strategies mediate relationship between EF impairment and depressive symptoms? Finally, the hypothesis that the relationship between EF impairment and depressive symptoms is mediated by maladaptive and adaptive ER was examined. The results indicate that both maladaptive and adaptive ER strategies are significantly associated with depressive symptoms (b-path; $\beta = .35$, $t = 10.06$, $p < .001$ and $\beta = -.27$, $t = -7.65$, $p < .001$, respectively). Moreover, the indirect effect of EF impairment on depressive symptoms through the mediators maladaptive and adaptive ER strategies (ab-path) was estimated to lie between .032 and .114 and between .001 and .078, respectively. Since the 95% confidence interval for the indirect pathways via maladaptive and adaptive ER does not include zero, this indicates a significant mediated pathway. With maladaptive and adaptive ER in the model, the direct effect of EF impairment on depressive symptoms (c-path; $\beta = .32$, $t = 5.50$, $p < .001$) decreases but remains significant (c’-path; $\beta = .20$, $t = 3.91$, $p < .001$), indicating partial mediation. The overall mediation model is significant, $F(7, 570) = 41.75$, $p < .001$ and explains 34% of the variance in depressive symptoms ($R^2 = .34$, adjusted $R^2 = .33$).


**Figure 1.** Maladaptive and adaptive ER as mediators between EF impairment and depressive symptoms. *Note. *p < .05; ***p < .001. EF = Executive Functioning; ER = Emotion Regulation.

**Discussion**

This study investigates the relationship between EF impairments, maladaptive and adaptive ER strategies, and depressive symptoms in adolescents. The primary aim of this study is to test whether EF impairment contributes to greater use of maladaptive and less use of adaptive ER strategies, which in turn lead to depressive symptoms. As hypothesized, the results indicate that EF impairments are associated with depressive symptoms and that this relationship is mediated by the use of both maladaptive and adaptive ER strategies.

**Executive Functioning Impairment and Depressive Symptoms**

Multiple studies have examined and supported the relationship between EF impairment and depression in adults (for a review see Snyder, 2013). However, studies examining this association in adolescents have been fewer in number and have yielded mixed results (for a review see Vilgis et al., 2015). While some studies in depressed or dysphoric adolescents have failed to find impairments on EF (Baune et al., 2014; Vilgis et al., 2015), findings from other recent studies have supported the presence of impairments on both global EF (e.g., Han et al., 2016; Holler et al., 2014) and different EF components.
Executive Functioning in Adolescents

For example, the results of Holler et al. (2014) indicate impairments on cognitive flexibility, working memory, and overall EF in depressed adolescents compared to healthy controls. Furthermore, the results of Han et al. (2016) show a significant association between global EF difficulties, as measured with the Wisconsin Card Sorting Test, and adolescent depressive symptoms. Despite the use of a behavioral rating scale of EF in everyday situations, the results of the present study are consistent with the abovementioned findings based on EF performance measures and indicate that greater EF impairment is significantly associated with greater depressive symptoms in adolescents. This is in line with the theoretical account that depression is associated with broad impairments in different components of EF and that these deficits may be related to the recurring negative thoughts and prolonged negative affect that characterize depression (Joormann et al., 2007; Porter, Gallagher, Thompson, & Young, 2003; Vilgis et al., 2015).

Emotion Regulation Strategies as a Mediator between Executive Functioning Impairment and Depressive Symptoms

The main goal of this study is to investigate the underlying mechanisms of the association between EF impairment and depressive symptoms. Although research in adults has already documented ER as having an important role in the relationship between EF impairment and depression, research in adolescents is lacking (e.g., Demeyer et al., 2012; Joormann & D'Avanzato, 2010). In line with the adult literature, the current findings show that the relationship between EF impairment and depressive symptoms is partially mediated by a more frequent use of maladaptive ER strategies and a less frequent use of adaptive ER strategies. Interestingly, the present results are also broadly in line with a study of Evans et al. (2016) on 9- and 15-year-olds indicating that the association between EF deficits and depressive symptoms is partially mediated by coping strategies in social situations.

The finding that EF impairment is related to a greater use of maladaptive ER strategies is consistent with a number of studies in depressed adults which indicate a significant relationship between cognitive impairments and rumination (e.g., Joormann et al., 2006; Joormann & Gottfib, 2008). Moreover, evidence for a mediating role of maladaptive ER strategies in the association between EF impairment and depressive symptoms was found in a study of Demeyer et al. (2012) conducted on adults which
indicates that cognitive impairment predicts depressive symptoms prospectively and that this relationship is partially mediated by rumination.

The present results indicate that a lower use of adaptive ER strategies also partially explains the association between EF impairment and depressive symptoms. Although existing research focusing on adaptive ER strategies is limited, the present results are congruent to those of Joormann and D’Avanzato (2010), who show that EF impairment is related to less use of cognitive reappraisal in both healthy and depressed adults.

Overall, the results of the current study provide evidence for the indirect effect of impaired EF on adolescent depressive symptoms through ER ability. Although the data are cross-sectional and do not permit conclusions about causal relationships, the current findings are consistent with the idea that deficits in global EF may lead to a greater use of maladaptive ER strategies and may interfere with the use of adaptive ER strategies and therefore increase the risk for developing depression (Joormann & D'Avanzato, 2010; Joormann et al., 2010).

**Clinical Implications**

The high relapse rates associated with adolescent depression indicate that the depression treatments which are currently available fail to improve long-term well-being because the fundamental mechanisms in the development and maintenance of depressive symptoms are still unknown (Lewinsohn et al., 1994; Pine, Cohen, Gurley, Brook, & Ma, 1998). Based on the results of the current study, preliminary clinical implications can be drawn. First, it can be assumed that an important variable to target in prevention and/or intervention programs for adolescent depression is ER. Specifically, programs focusing on improving the use of adaptive ER strategies as well as reducing the use of maladaptive ER strategies may increase the capacity of adolescents to deal with emotional stress and reduce the risk of developing depressive symptoms. However, a focus on ER strategies might not be sufficient since the results of current study also support a fundamental role of EF in depressive symptoms. Therefore, an additional cognitive control training to address EF deficits might be particularly important for targeting the basic underlying processes of depression and improving relapse rates. Specifically, cognitive training programs may improve EF processes which are crucial for goal-directed and adaptive behavior in a changing environment. In turn, the training of EF may increase the use of adaptive ER strategies such as cognitive reappraisal or problem-solving. Importantly, research in adults already provided first evidence for a significant effect of cognitive control training
targeting working memory on ER and stress reactivity (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015; Siegle, Ghinassi, & Thase, 2007).

**Study Strengths, Limitations, and Future Research**

The main strength of the study lies in its focus on cognitive and emotional risk factors for depression in adolescents. Since adolescence represents a critical period of vulnerability to depression and given the elevated risk of a depressive disorder in adulthood following first-onset depression in adolescence (Fombonne, Wostear, Cooper, Harrington, & Rutter, 2001), further research on the underlying mechanisms of the etiology and recurrence depression in this age group is needed. Furthermore, in contrast to other studies focusing on the role of specific maladaptive (e.g., rumination) or adaptive ER strategies (e.g., cognitive reappraisal) (e.g., Demeyer et al., 2012; Joormann & D'Avanzato, 2010), the current study focuses on the joint effect of adaptive and maladaptive ER strategies. This corresponds to the idea that the broad range of maladaptive and adaptive ER strategies an individual has at his or her disposal should be considered when evaluating the risk of psychopathology, and of depression in particular. Moreover, it is suggested that a wider range of available adaptive strategies might offer the individual a greater flexibility to adequately deal with negative emotions, while a wider range of maladaptive strategies might reflect one’s general dysfunction to deal with emotions or emotion-eliciting events (Yap et al., 2011). Finally, while ER strategies and depressive symptoms were measured using self-report questionnaires, EF impairments and general psychopathology were assessed using parent-report questionnaires. This multi-information approach reduces reporter-bias and lessens the problem of common method variance. Specifically, obtaining all data with the use of self-reports may inflate associations between variables through shared method variance (Lindell & Whitney, 2001).

However, in interpreting the results of this study, several limitations should be acknowledged. First, the current study is limited by the cross-sectional nature of its design. Prospective studies certainly provide the most stringent test of research questions, but these studies are not always the first and most economical step. Nevertheless, future longitudinal studies are needed to replicate this study in order to determine temporal consequences and to explore whether EF impairments prospectively lead to depressive symptoms through the use of adaptive and maladaptive ER strategies. Second, the current study used the CDI, a well-validated self-report questionnaire (Kovacs, 1992; Dutch version by Timbremont & Braet, 2002), to assess depressive symptoms - yet, the use of a
structured clinical interview is required to diagnose the presence of a major depressive disorder, either currently or in the past (Hien et al., 1998). However, because of the subtle subclinical and the different clinical presentations of depression, identifying mildly and clinically depressed adolescents using a categorical diagnostic interview is rather difficult (Girio-Herrera & Ehrenreich-May, 2014). In contrast, dimensional scales, such as the CDI, allow the examination of the level of depressive symptomatology and the investigation of associations of EF with depressive symptoms (Avenevoli et al., 2008). Nevertheless, it would be interesting to test this mediation model in currently- and previously depressed adolescents to explore whether EF impairment acts as a vulnerability factor for the development and maintenance of major depressive episodes. Another limitation is that EF impairments were assessed with the use of a questionnaire (BRIEF; Gioia et al., 2000). Although the BRIEF is a well-reported screening questionnaire and is shown to be an ecologically valid measure of the multidimensional concept of EF (Gioia & Isquith, 2004; Gioia, Isquith, Retzlaff, et al., 2002), experimental laboratory tasks appear to be more specific measures of operating cognitive processes (Clark, Beck, & Alford, 1999; Gotlib & Krasnoperova, 1998; Rude, Covich, Jarrold, Hedlund, & Zentner, 2001).

To conclude, the present study highlights the important role of both maladaptive and adaptive ER in explaining the relationship between EF impairment and depressive symptoms. These results add to the growing evidence that identifying fundamental affective and cognitive processes underlying the etiology and maintenance of depression can improve current prevention and treatment programs.
Acknowledgements

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Abstract

Recent cognitive models suggest that the ability to control emotional information in working memory (WM) may be implicated in the etiology and maintenance of depression. However, few studies have examined the effects of processing relevant and irrelevant emotional stimuli on WM performance in depressed adolescents. In the current study, depressed (n = 27) and non-depressed (n = 49) adolescents completed two versions of an emotional n-back task: a low WM load (0-back) and high WM load (2-back) task. In the emotion-relevant condition participants were asked to attend to the emotional expression of an angry, happy or neutral face, while in the emotion-irrelevant condition participants were asked to attend to the gender of the face. The results showed a WM improvement for happy faces in the emotion-relevant condition and a WM impairment for happy faces in the emotion-irrelevant condition for non-depressed adolescents, but not for depressed adolescents. No information processing biases towards angry faces were found. These results suggest differential processing of positive information in depressed adolescents compared to healthy adolescents and may provide new insights for future prevention and intervention programs.
Introduction

Major depressive disorder (MDD) is among the most severe and debilitating mental disorders, constitutes a high economic burden, and increases significantly in prevalence during adolescence (AACAP, 2007). Previous studies reported recurrence rates up to 75% and showed a six-fold higher risk of suicide associated with adolescent depression (Fombonne, Wostear, Cooper, Harrington, & Rutter, 2001a, 2001b), emphasizing the need for further research on underlying mechanisms of MDD in this age group. The model of Beck (1976) suggests that schematically driven automatic information processing, which results in attentional biases, interpretation biases, and memory biases, is a key mechanism in the development of depressive disorders. Recently however, cognitive theories also emphasize a significant role of cognitive control in the etiology and maintenance of depression (De Raedt & Koster, 2010; Joormann, Yoon, & Zetsche, 2007; Koster, De Lissnyder, Derakshan, & De Raedt, 2011), and a flexible working memory (WM) regarding the processing of emotional stimuli in particular (Levens & Gotlib, 2010). Given that updating the contents of WM is essential to refocus attention or to reinterpret emotion-eliciting situations, a flexible WM is hypothesized to affect one’s ability to regulate emotions and, in turn, the risk of developing MDD (Joormann, Yoon, & Siemer, 2010; Schmeichel & Tang, 2015). This is consistent with the conceptualization of WM as the processes that allow an individual to briefly store, manipulate or update information, necessary to perform complex cognitive or behavioral tasks (Baddeley, 2010).

In the context of emotional information, WM is often assessed using an emotional variant of an n-back task, in which participants are presented with a series of stimuli and are asked to indicate whether the current stimulus matches the stimulus presented n-trials before. Whereas studies in adults document clear associations between impaired updating of the emotional content of WM and depression (e.g., Kerestes et al., 2012; Levens & Gotlib, 2010), studies on WM in adolescents have been scarce and findings have been mixed (Ladouceur et al., 2005; Tavitian et al., 2014). Using an n-back task Ladouceur et al. (2005) reported slower reaction times (RTs) to neutral target stimuli in the presence of negative background scenes in depressed adolescents and slower RTs in the presence of positive background scenes in healthy adolescents. In contrast, regarding accuracy rates, Tavitian et al. (2014) showed that, in comparison with healthy adolescents, depressed adolescents’ WM performance on neutral target stimuli was less accurate in the presence of neutral distractor faces but not with angry or happy distractor faces.
Noteworthy is that the emotional stimuli in the study of Ladouceur et al. (2005) and Tavitian et al. (2014) merely served as distractors during the performance of a non-emotional WM task. Arguably, however, the influence of emotional stimuli on cognitive control processes depends on the task-relevance of these stimuli (Kanske, 2012). When emotional stimuli serve as distractors and are irrelevant, performance will be impaired due to their preferential processing. However, when emotional stimuli are relevant and require attention, their automatic and prioritized processing will have beneficial effects on task performance (Cromheeke & Mueller, 2014). Levens and Gotlib (2010) explored the ability to store and update affective information in WM in depressed adults and used an n-back task in which emotional information was relevant. Depressed participants had a tendency to keep negative information active in WM, while healthy participants showed the reverse pattern and were slower to disengage from positive information compared to neutral or negative information. While comparative studies in mood-disordered adolescent are currently lacking, a study in healthy adolescents indicated WM improvement for happy faces when emotion was task-relevant but an impairment for these stimuli when they were task-irrelevant, indicating a positivity bias in healthy participants (Cromheeke & Mueller, 2015).

Besides task-relevance of emotional stimuli, also the level of cognitive load of a task is of importance, whereby specifically under high WM demands a reduced ability to suppress irrelevant emotional stimuli is expected (Eysenck, Derakshan, Santos, & Calvo, 2007; Kerestes et al., 2012; Lavie, 2010). Therefore, the current study compared the effects of relevant and irrelevant emotional stimuli on WM in depressed and non-depressed adolescents using two versions of an emotional n-back task: a low WM load (0-back) and a high WM load (2-back) task. The investigation of emotional processing in WM is of particular interest since it has been shown that the capacity to control incoming information in WM positively impacts one’s ability to deal with stressful events and to manage emotional responses (Ochsner & Gross, 2005). This emotion-regulating role indicates that a flexible and well-functioning WM represents an important buffer in the onset of mental health problems and suggests that targeting basic cognitive process may improve the effectiveness of depression prevention programs (Pe, Koval, & Kuppens, 2013). Moreover, it is highly relevant to study these processes in an adolescent age group, given that adolescence represents a particularly vulnerable period for the development of a depressive disorder (Dahl, 2004). Part of this increased vulnerability can be found in ongoing brain development that is characterized by an imbalance between an early
maturation of subcortical “affective” regions, such as the amygdala, and a late maturation of prefrontal cortical regions involved in cognitive control processes (Ernst, Pine, & Hardin, 2006).

Based on cognitive theories of depression (De Raedt & Koster, 2010; Joormann et al., 2007; Koster et al., 2011) and the results of prior emotional n-back studies in depressed adolescents and young adults (Ladouceur et al., 2005; Levens & Gotlib, 2010; Tavitian et al., 2014), we hypothesized an impairment in the processing of negative information in WM in depressed adolescents compared to non-depressed adolescents. In an emotion-irrelevant (gender) focus condition, we expected angry faces to be more distracting and to impair WM performance more so in depressed adolescents compared to healthy adolescents. In an emotion-relevant (valence) focus condition, we expected a performance improvement for angry faces in depressed adolescents compared to healthy adolescents. Moreover, based on Cromheeke and Mueller (2015), we expected the reverse pattern in healthy adolescents, i.e., a WM performance impairment for happy faces during the gender condition and an improvement for happy faces during the valence condition.

**Materials and Methods**

**Participants**

Fifty-three healthy adolescents (28 girls; mean age = 14.21, SD = 1.48) and 57 referred adolescents (21 girls; mean age = 14.68, SD = 1.62) participated in the study. Healthy adolescents were recruited through advertising in schools. The referred adolescents were recruited from different clinical centers and were invited if they were referred for treatment of internalizing problems. Inclusion criteria for all participants were: (a) age between 10-18 years and (b) IQ within the normal range (≥ 70). In order to screen for psychopathology, the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001) was filled out by a parent or caregiver. In addition, a trained psychologist administered the “depressive disorders module” of a semi-structured interview for DSM-5 disorders (SCID-Junior; Braet, Wante, Bögels, & Roelofs, 2015) to assess the presence of depressive disorders. Three comparison adolescents were excluded based on clinical scores (T > 70) on the internalizing, externalizing, or total problems scale of the CBCL or a present or past depression diagnosis. Sixteen referred adolescents were excluded because of the absence of a present or past depression diagnosis. The research protocol was approved by the Ethics Committee of the University Hospital. Youngsters signed informed assent while legal
guardians signed informed consent. After completing the questionnaires and the task, participants were compensated with two cinema tickets.

**Self-report measures**

**Depressive symptoms.** The Children's Depression Inventory (CDI; Kovacs, 1992; Dutch version by Timbremont & Braet, 2002) is a 27-item self-report questionnaire designed to assess depressive symptoms in youth. The CDI showed good psychometric qualities in terms of internal consistency and test-retest reliability in non-clinical samples (Craighead, Smucker, Craighead, & Ilardi, 1998; Timbremont & Braet, 2002). Cronbach’s alpha on the CDI in the present sample was α = .93.

**Anxiety symptoms.** The trait version of the State-Trait Anxiety Inventory for Children (STAI-TC; Bakker, Wieringen, Ploeg, & Spielberger, 2004; Spielberger, 1973) is a 20-item self-report questionnaire that assesses the frequency and intensity of anxiety symptoms. The STAI-TC is considered as a reliable and valid measure for assessing anxiety symptoms in youngsters. Internal consistency in this study was good with a Cronbach’s alpha of .89.

**Clinical interview**

Depressive disorders were assessed using the SCID-Junior (Braet et al., 2015). This semi-structured interview for DSM-5 disorders is a recent modification of the Kid-SCID (Hien et al., 1998), a widely used diagnostic interview for DSM-IV disorders in children that has moderate to good inter-rater reliability and internal consistency (Roelofs, Muris, Braet, Arntz, & Beelen, 2015; Smith, Huber, & Hall, 2005; Van Vlierberghe, Braet, Goossens, & Mels, 2008).

**Intelligence**

An intelligence score was calculated by using an abbreviated version of the Dutch Wechsler Intelligence Scale for Children III (WISC-III; Kort, 2002). This shortened version has been found to be reliable and valid (Sattler, 1992; Strauss, Sherman, Spreen, & Spreen, 2006) and consists of two subtests: Vocabulary and Block Design.

**Emotional n-back task**

The n-back task was programmed in Presentation software and was run on a 15.6” Dell laptop. The pictorial stimuli for the experimental trials were selected from two validated databases: the NimStim (Tottenham et al., 2009) and the Radboud Faces Database (Langner et al., 2010). For the practice trials, 14 faces were selected from the Karolinska Directed Emotional Faces database. Each actor posed three emotional
expressions, resulting in a final stimulus set of 33 neutral faces, 33 happy faces and 33 angry faces. The pictures were set at 320 x 440 pixels and were grayscaled.

The participants completed two versions of the emotional n-back task: a 0-back and a 2-back task. In both versions of the task, there were two conditions: a gender condition in which participants had to focus on the gender of the faces and a valence condition in which participants had to attend to the emotional expression of the faces. In the 0-back task, participants were asked to respond to a target. In the gender condition the target was a male or a female face (e.g., is this a male face?), while in the valence condition the target was an angry, happy or neutral facial expression (e.g., is this an angry face?). Participants were instructed to press the left mouse button if the presented face was the target, and the right mouse button when the presented face was not a target. In the gender condition of the 2-back task, participants were asked to compare the gender of the current face with the gender of the face presented two trials before. In the valence condition of the 2-back task, participants had to indicate whether the emotional expression of the current face matched the expression of the face presented two trial before. The 2-back task consisted of match and mismatch trials. A match trial refers to a trial in which the faces or gender are the same, a mismatch trial refers to a trial in which the faces or gender are different. Participants were asked to press the left mouse button for a match trial and the right mouse button for a mismatch trial. Pictures were presented for 2000 ms, with a 500 ms intertrial interval (see Figure 1).

To avoid differences in difficulty of the gender and valence attention condition, only two emotions were shown in each block (angry and neutral, happy and neutral, or angry and happy faces). The 0-back task consisted of 12 blocks of 12 trials. Each of these blocks comprised a different combination of emotions (angry-neutral, happy-neutral, or angry-happy faces), condition (focus on gender or valence) and target (one of both emotions or gender categories). The 2-back task consisted of 6 blocks of 32 trials with each block being a different combination of emotions (angry-neutral, happy-neutral, or angry-happy faces) for each condition (gender or valence). The order of WM load versions (0-back or 2-back) was counterbalanced across participants and within the WM load versions adolescents started either with the gender or the valence condition. Moreover, within the conditions, combinations of emotions were shown in a random order. Finally, and in order to avoid familiarity effects and confusion with identity, each actor was presented only once in a block.
Figure 1. Experimental design of the emotional 2-back task. In the valence condition, match trials refer to trials in which the emotional expression of the target picture matches the emotional expression on the picture two trials back. In the gender condition, match trials refer to trials in which the gender of the target picture matches the gender of the picture that appeared two trials earlier. Pictures were presented for 2000 ms, with a 500 ms intertrial interval.

Procedure

Healthy adolescents were invited to the lab at the Faculty of Psychology and Educational Sciences, while referred adolescents were tested in a neutral room at the treatment center. After signing assent/consent, participants were seated in front of a computer and task instructions were displayed on the computer screen. To ensure clarity of the instructions, these were also repeated orally by the experimenter. Before starting with the experiment proper, participants completed practice trials and were able to ask for help if needed. The practice blocks consisted of 10 trials for the 0-back task and 24 trials for the 2-back task. Only if participants had an accuracy rate of at least 60% on the practice blocks, they could continue with the experimental blocks. After finishing the n-back task,
all participants completed the Vocabulary and Block Design test of the WISC-III. At the end of the experiment, subjects completed the CDI and the STAI-TC.

**Data Analyses**

Data were log10 transformed because of non-normal distribution. A repeated-measures analysis of covariance (RM-ANCOVA) with Load (0-back, 2-back), Condition (gender, valence), and Emotion (angry, happy, neutral) as within-subjects factor and Group (depressed, healthy) as between-subjects factor was conducted for the mean correct RT and accuracy (% correct), separately. Age and intelligence score of the participants were included as standard covariates in all analyses. Moreover, since depression and anxiety are frequently associated with one another (AACAP, 2007) and to exclude a potential contributing factor, we reran the RM-ANCOVA with anxiety symptoms as a covariate of no interest. Since the interactions with group (depressed vs. healthy) remained unchanged, the results of this additional analysis are not further discussed. To further investigate significant interactions, paired-samples t-tests were performed. Finally, to assess the contribution of symptom severity, correlation analyses were performed between CDI and STAI-TC scores and the different performance variables. Effects sizes are provided as eta squared ($\eta^2$) and Cohen’s $d$. Alpha was set at $p = 0.05$, two-tailed. For every participant, trials with incorrect responses or outliers were removed for the RT analysis. Outliers were defined as RTs that deviated more than 3 SDs from the individual mean RT for the 0-back and 2-back separately (Cromheeke & Mueller, 2015).

**Results**

**Group Characteristics**

Fourteen subjects from the depressed group (13%) compared to one of the healthy group (1%) were excluded, because they failed to reach a minimum accuracy rate of 60% on the practice blocks of the 2-back task and thus did not continue with the experimental blocks, $\chi^2 (1, 110) = 13.19, p < .001$. As a result, the task was completed by 27 adolescents meeting DSM-5 criteria for MDD current ($n = 20$) or past ($n = 7$) (20 girls; mean age = 14.81, $SD = 1.64$) and 49 non-depressed adolescents (28 girls; mean age = 14.33, $SD = 1.57$). There were no significant differences between the included and excluded depressed adolescents on depressive symptoms (CDI) or anxiety symptoms (STAI-TC), $F(2, 44) = .639, p = .532, \eta^2 = .03$. In the final sample, depressed adolescents had significantly elevated depressive symptoms relative to comparisons, $F(1, 65) = 77.31, p < .001, \eta^2 = .54$. One-way ANOVAs also indicated significant group differences on anxiety symptoms,
F(1, 65) = 65.81, p < .001, η² = .50, and intelligence as measured with two subtasks from the WISC-III, (1, 65) = 16.66, p < .001, η² = .20. No significant group differences were present for age or gender distribution (all p > .14) (Table 1).

### Table 1
*Characteristics of the sample*

<table>
<thead>
<tr>
<th></th>
<th>Depressed</th>
<th>Non-depressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>27</td>
<td>49</td>
</tr>
<tr>
<td>Depressive symptoms***</td>
<td>20.54 (9.80)</td>
<td>6.39 (3.55)</td>
</tr>
<tr>
<td>Anxiety symptoms***</td>
<td>45.14 (6.55)</td>
<td>31.77 (5.94)</td>
</tr>
<tr>
<td>Age</td>
<td>14.81 (1.64)</td>
<td>14.33 (1.57)</td>
</tr>
<tr>
<td>Intelligence***</td>
<td>16.84 (4.78)</td>
<td>21.18 (3.72)</td>
</tr>
<tr>
<td>Sex (female/male)</td>
<td>20/7</td>
<td>28/21</td>
</tr>
</tbody>
</table>

*Note.* ***p < .001. Intelligence = An intelligence score was calculated by summing the standard scores on Vocabulary and Block design for each participant. SDs are in parentheses.

### Reaction Time

As expected, a significant four-way interaction among Load, Condition, Emotion, and Group emerged, F(2, 69) = 4.27, p = .018, η² = .11. To explore this result, an ANCOVA with Condition and Emotion as within-factors and Group as between-subjects factor was run for the low load WM condition (0-back) and the high load WM condition (2-back), separately (Figure 2). Only during high WM load results revealed a significant three-way Condition by Emotion by Group interaction, F(2, 69) = 7.27, p = .001, η² = .17. To understand this three-way interaction, a Condition by Emotion analysis of variance (ANOVA) was run for depressed and healthy adolescents, separately. In depressed adolescents no significant findings emerged (all ps > .12). In healthy adolescents, the Condition by Emotion interaction was significant, F(2, 47) = 10.02, p < .001, η² = .30, indicating slower RTs for happy faces in the gender relative to the valence condition, t(48) = 3.69, p = .001, d = .51. No differences were found for angry or neutral faces. Analyses within Conditions revealed slower RTs for happy faces when compared to angry faces,
$t(48) = 2.09, p = .042, d = .31$, and neutral faces, $t(48) = 3.01, p = .004, d = .43$, in the gender condition. In the valence condition, RTs were faster for happy faces compared to angry faces, $t(48) = -2.97, p = .005, d = -.43$, and neutral faces, $t(48) = -2.11, p = .04, d = -.43$.

**Figure 2.** * $p < .05$; ** $p < .01$. (A) RTs (ms) for healthy adolescents (left panel) and depressed adolescents (right panel) in the 0-back task. (B) RTs (ms) for healthy adolescents (left panel) and depressed adolescents (right panel) in the 2-back task. Error bars represent standard error of the mean.
In order to compare the effects of happy faces between depressed and healthy adolescents, one-way ANOVAs were conducted on RT difference scores (DS; RT happy faces in valence condition - RT happy faces in gender condition). This DS was significantly larger in healthy adolescents compared to depressed adolescents, $F(1, 75) = 9.81, p = .002, \eta^2 = .12$. In addition, DS within Conditions were calculated. The DS between happy and angry faces, $F(1, 75) = 8.57, p = .005, \eta^2 = .10$, and between happy and neutral faces, $F(1, 75) = 6.56, p = .012, \eta^2 = .08$, were larger in healthy adolescents compared to depressed adolescents in the gender condition. Also in the valence condition, the DS were larger in healthy adolescents compared to depressed adolescents, (happy-angry: $F(1, 75) = 4.25, p = .043, \eta^2 = .05$; happy-neutral: $F(1, 75) = 4.54, p = .036, \eta^2 = .06$) (Figure 3).

Figure 3. *$p < .05$; **$p < .01$. RT difference scores (ms) for the gender and the valence condition in both the healthy and the depressed group. Positive scores indicate slower RTs to happy faces compared to either angry or neutral faces. Error bars represent standard error of the mean.
Response Accuracy

In the accuracy data (Table 2), Load interacted with intelligence, $F(1, 70) = 7.09, p = .01, \eta^2 = .09$. Follow-up analyses showed that intelligence correlated positively with accuracy rates on the 2-back task, $r(73) = .37, p = .001$, while there was no significant correlation with accuracy rates on the 0-back task, $r(73) = .05, p = .677$. However, the expected four-way interaction among Load, Condition, Emotion, and Group did not emerge.

Table 2
Mean reaction times (in ms) and accuracy rates (in %) on the 0-back task (upper half) and the 2-back task (lower half) as a function of group

<table>
<thead>
<tr>
<th>0-back task</th>
<th>Depressed</th>
<th></th>
<th>Non-depressed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Condition</td>
<td>Emotion</td>
<td>RT (ms)</td>
<td>ACC (%)</td>
</tr>
<tr>
<td>Gender task</td>
<td>Angry</td>
<td>789 (136)</td>
<td>86 (11)</td>
<td>856 (417)</td>
</tr>
<tr>
<td></td>
<td>Happy</td>
<td>784 (147)</td>
<td>90 (9)</td>
<td>844 (121)</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>782 (141)</td>
<td>92 (10)</td>
<td>852 (133)</td>
</tr>
<tr>
<td>Valence task</td>
<td>Angry</td>
<td>780 (144)</td>
<td>90 (7)</td>
<td>850 (135)</td>
</tr>
<tr>
<td></td>
<td>Happy</td>
<td>753 (117)</td>
<td>93 (9)</td>
<td>802 (145)</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>813 (145)</td>
<td>94 (8)</td>
<td>887 (153)</td>
</tr>
<tr>
<td>2-back task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender task</td>
<td>Angry</td>
<td>1071 (197)</td>
<td>63 (12)</td>
<td>1165 (201)</td>
</tr>
<tr>
<td></td>
<td>Happy</td>
<td>1024 (234)</td>
<td>67 (11)</td>
<td>1201 (206)</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>1047 (229)</td>
<td>69 (15)</td>
<td>1150 (195)</td>
</tr>
<tr>
<td>Valence task</td>
<td>Angry</td>
<td>1051 (195)</td>
<td>66 (14)</td>
<td>1163 (203)</td>
</tr>
<tr>
<td></td>
<td>Happy</td>
<td>1062 (218)</td>
<td>68 (16)</td>
<td>1112 (204)</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>1053 (222)</td>
<td>68 (16)</td>
<td>1166 (251)</td>
</tr>
</tbody>
</table>

Note. RT = reaction time; ACC = accuracy rates. Standard deviations are in parentheses.
Effects of Depressive and Anxiety Symptom Severity

CDI and STAI-TC scores were not significantly correlated with the different performance variables (all \( ps > .05 \) after correction for multiple comparisons).

Discussion

This study investigated the effects of relevant and irrelevant emotional stimuli on WM in depressed and healthy adolescents. Contrary to expectations, angry faces did not influence WM performance in depressed adolescents. However, as hypothesized, happy faces improved WM performance in the valence condition and impaired WM performance in the gender condition in healthy adolescents, whereas this effect was not present in depressed adolescents. Specifically, in healthy adolescents, happy faces led to faster RTs in the valence condition and to slower RTs in the gender condition compared to angry and neutral stimuli and in comparison with depressed adolescents.

Overall, within the context of WM, the current results suggest that depressed adolescents do not show a preferential processing of negative faces, but rather fail to demonstrate a memory bias to positive faces as seen in healthy comparisons. This is in line with parallel research on attention (Ellis, Beevers, & Wells, 2011; McCabe & Gotlib, 1995) and self-referent encoding and recall (Timbremont & Braet, 2004) indicating that depressed or dysphoric individuals do not show biases while healthy participants exhibit a positivity bias. The results further align with studies on emotional reactivity, which indicate blunted emotional response to positive emotional stimuli in depressed individuals (Canli et al., 2004; Rottenberg, Gross, & Gotlib, 2005; Sloan, Strauss, & Wisner, 2001). In addition, the results in the comparison group correspond to the n-back studies of Cromheeke and Mueller (2015) and Ladouceur et al. (2005) in which positive information affected WM performance in healthy adolescents.

The finding that in depressed adolescents WM processes do not lead to a positivity bias that is evident in healthy adolescents converges with the theoretical notion of depressive realism and non-depressive optimistic biases (Alloy & Abramson, 1988; Alloy, Albright, Abramson, & Dykman, 1990). In essence, this notion suggests that depressed individuals show a tendency to perceive and interpret information in a realistic and accurate manner, whereas healthy individuals utilize self-enhancing or positivity biases. This kind of information processing may be a mechanism reflecting the interpersonal difficulties that are associated with depression (Hames, Hagan, & Joine, 2013). Specifically, it can be hypothesized that depressed adolescents attend positive social
information to a lesser extent compared to healthy adolescents, which may in turn lead to the perception of a lack of social support and a low self-esteem (Gotlib & Hammen, 2002; Joormann & Gotlib, 2007).

In contrast to our findings in WM, a previous affective priming study in dysphoric youth demonstrated a bias towards angry faces (Wante, Mueller, Demeyer, De Raedt, & Braet, 2015). The explanation for these contradictory results may be found in the focus on different cognitive control functions (i.e., selection/inhibition vs. WM). Previous work has provided evidence that distinct cognitive control functions, such as inhibition and WM, are moderately correlated but yet are clearly distinct from one another (Miyake et al., 2000) and show different developmental trajectories (Best & Miller, 2010). Furthermore, the results in the depressed group also differ from prior n-back studies that used emotional stimuli as distractors and non-emotional stimuli as target stimuli and reported slower RTs in the presence of negative background scenes (Ladouceur et al., 2005) and lower accuracy rates in the context of neutral distractor faces in depressed adolescents compared to healthy adolescents (Tavitian et al., 2014). The present study differed from these prior two studies in two crucial ways: 1) we assessed both relevant and irrelevant emotional information, and 2) the two tasks (gender/valence) were contained within the same stimuli as opposed to separated distractor and target stimuli. Therefore, the diverging results may be explained by the different nature of the tasks and/or stimuli involved.

In any case, the findings are in line with theoretical notions of how affective information should influence high cognitive load and WM (Eysenck et al., 2007; Lavie, 2010). According to the Attentional Control Theory (ACT; Eysenck et al., 2007), affective information should only influence cognitive control processes when cognitive load is high. In the current study, the beneficial effect of happy faces in task-relevant conditions was only observed in the high load WM task, which suggests that healthy adolescents experience difficulties filtering positive information especially when task demands are high and cognitive resources are limited.

Clinically, the present results suggest an important role of emotional processing in WM in future prevention or intervention programs for adolescent depression. Notably, a significantly larger proportion of the depressed group compared to the healthy group failed to reach a minimum accuracy rate of 60% on the practice blocks of the high load WM task. This finding points to a general WM impairment in depressed adolescents and corresponds to previous studies indicating general cognitive control deficits in depressed versus healthy adolescents (for a review see Wagner, Muller, Helmreich, Huss, & Tadic, 2015).
cognitive control training (CCT) targeting general WM capacity may improve goal-directed and adaptive behavior in a changing environment in at-risk or depressed adolescents (Gyurak, Goodkind, Kramer, Miller, & Levenson, 2012). Research in adults already provided evidence for a significant effect of CCT targeting WM on ER and stress reactivity (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015; Siegle, Ghinassi, & Thase, 2007). However, parallel research in depressed adolescents focusing on WM is currently lacking.

Furthermore, WM processing in depressed adolescents may be related to problems in emotion regulation (ER). Specifically, in real life, when different emotional stimuli are attracting attention, reduced attention for positive information may hinder the use of adaptive ER strategies, such as positive refocusing, and lead to an exacerbation of negative affect (Sanchez, Vazquez, Gomez, & Joormann, 2014). In this context, an interesting avenue for future research is to explore the impact of a cognitive program designed to train attention towards positive information on depressed or at-risk adolescents’ ER ability. Interestingly in this respect, a recent study in pediatric anxiety demonstrated promising effects of such a “positive attention training” (Waters, Pittaway, Mogg, Bradley, & Pine, 2013). In addition, a review of Wadlinger and Isaacowitz (2011) demonstrated positive effects of various attentional training programs on ER ability in adults.

Some study limitations should be noted. First, in contrast to multiple studies (e.g., Joormann & Gotlib, 2007; Levens & Gotlib, 2010) that focused on cognitive control over sad stimuli, the current study investigated the effect of angry facial expressions on WM in depressed adolescents. Since sad faces were not included in our stimulus set, we could not compare the effects of different types of negative stimuli on WM performance. In addition, the current study is limited by the cross-sectional nature of its design preventing definitive conclusion whether impaired WM performance and the absence of a positivity bias prospectively lead to the development of a depressive disorder.

Conclusions

In conclusion, depressed adolescents relative to healthy comparisons fail to show the protective positivity bias when WM demands are high and suggest that the processing of emotional information in WM may be a promising target for future depression prevention and treatment programs. Future research that examines the prospective effects of impaired WM on adolescent depression is warranted.
Acknowledgements

This study was supported by Special Research Fund of Ghent University (Belgium) [grant number 01D31513]. The authors thank the MultiFunctional Center ‘Capelderij’, the Observation and Orientation Center ‘Luein’, and the Rehabilitation Center ‘Zeepreventorium’ for patient gathering.
EMOTIONAL PROCESSING IN DEPRESSED ADOLESCENTS

References


EMOTIONAL DISTRACTION INFLUENCES HEALTHY BUT NOT DYSPHORIC ADOLESCENTS DURING WORKING MEMORY¹

Abstract

Altered processing of emotion during cognitive control performance has been suggested to play an important role in the etiology and persistence of depressive symptoms. Despite increasing research in adults, few studies have explored the influence of emotion on cognitive control processes in depressed or dysphoric youth. Therefore, the current study aims to investigate the influence of irrelevant emotional stimuli on working memory (WM) performance in dysphoric adolescents. Twenty-five dysphoric (20 girls) and 40 non-dysphoric adolescents (25 girls) completed a memory-guided eye movement task. In the low load WM condition participants were asked to remember the location of two target stimuli, whereas in the high load WM condition they had to remember the location of four target stimuli. Importantly, the to-be-remembered target stimuli were colored rectangles which contained irrelevant affective information. Latency analyses showed that, in the high load WM condition, negative distractors disturbed WM performance in the non-dysphoric group. No effects of emotional distractors were observed in the dysphoric group. Accuracy analyses revealed that non-dysphoric adolescents had higher accuracy rates in the presence of positive distractors relative to negative and neutral distractors, and in comparison to dysphoric adolescents who had lower accuracy rates in the context of positive

distractors. This effect on accuracy, however, disappeared when controlling for the possible impact of comorbid anxiety symptoms. The findings indicated unaffected WM performance in the context of irrelevant emotional distractors in dysphoric adolescents and may contribute to theoretical knowledge and early prevention of youth depression.
Introduction

Dysphoria, or subclinical depression, is a common mental health condition in adolescents associated with detrimental outcomes, such as school failure and social impairment, and an increased risk for chronic depression in adulthood (Allen, Chango, Szwedo, & Schad, 2014; Balazs, 2013; Lewinsohn, Rohde, Seeley, Klein, & Gotlib, 2000; Salmela-Aro, Savolainen, & Holopainen, 2009). Although it is clear that dysphoria is a substantial and worldwide problem among young adolescents (Hankin, 2006), little is known about cognitive and emotional underpinnings of depressive symptoms in this age group.

Building on Beck’s cognitive model of depression (Beck, 1976), an important set of recent theories highlight a crucial role of cognitive control deficits in the development and maintenance of depression. In these theories (Joormann, Yoon, & Zetsche, 2007; Koster, De Lissnyder, Derakshan, & De Raedt, 2011), it is suggested that depressed individuals prioritize the processing of irrelevant negative emotional stimuli to the detriment of adequate cognitive control performance. Cognitive control is essential for adaptive behavior and refers to two basic abilities: (a) selecting and maintaining relevant goals while inhibiting irrelevant information, and (b) flexibly shifting attention in accordance to internal needs or a changing environment (Altamirano, Miyake, & Whitmer, 2010; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004).

One of the key executive function processes that is associated with cognitive control ability is working memory (WM), which is conceptualized as a limited-capacity resource system responsible for brief storage and manipulation of goal-relevant information and is associated with the prefrontal cortex of the brain (Baddeley, 2003). Given its limited capacities, efficient WM functioning is essential to refocus attention to new information or to reinterpret situations (Joormann & D'Avanzato, 2010). Therefore, it is hypothesized that a flexible WM in response to emotional information affects one’s ability to regulate emotions and, in turn, the risk of developing depressive symptoms (Joormann, Yoon, & Siemer, 2010; Schmeichel & Tang, 2015). Interestingly, it is assumed that WM is particularly sensitive to distracting emotional information during adolescence as this development period is characterized by ongoing prefrontal brain maturation and an increased emotional and stress reactivity (Anderson, 2002; Spear, 2009; Zelazo & Carlson, 2012). To date, however, the influence of
emotional stimuli on cognitive control, and WM in particular, has received scant empirical attention in depressed or dysphoric adolescents, although this interaction has been well documented among adults (for a review see Mueller, 2011).

In line with influential cognitive models of depression (Beck, 1976; Joormann et al., 2007; Koster et al., 2011), multiple studies provide evidence for a deleterious effect of negative emotion on cognitive control in depressed adults (for a review see Gotlib & Joormann, 2010). For instance, it has been shown that depressed individuals have difficulties disengaging attention from negative information and removing irrelevant negative content from WM (Joormann & Gotlib, 2008; Levens & Gotlib, 2010). However, a relatively small number of studies explored the interaction between cognitive control and emotion in depressed adolescents and results have been mixed. For instance, an n-back study, commonly used to assess WM, reported WM impairment in the presence of negative distractor stimuli in depressed adolescents (Ladouceur et al., 2005). Likewise, studies using the affective go/no go task demonstrated a bias to negative emotions in depressed adolescents (Kyte, Goodyer, & Sahakian, 2005; Ladouceur et al., 2006; Maalouf et al., 2012). In contrast, an n-back study of Tavitian et al. (2014) showed that, in comparison with healthy adolescents, depressed adolescents’ WM performance on neutral target stimuli was less accurate in the presence of neutral distractor faces but not with angry or happy distractor faces. Furthermore, another study using the affective and the face go/no go task failed to find reaction time differences between depressed adolescents and healthy comparisons (Han et al., 2012).

Of note, the effects of emotion on cognitive control may be modulated by the cognitive demands of a task. According to the Attentional Control Theory (ACT; Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007), emotions and emotional stimuli will particularly affect cognitive control processes under high cognitive demands. Specifically, tasks with high cognitive demands, as compared to tasks with low cognitive demands, require a substantial amount of cognitive resources, leaving individuals with insufficient resources to inhibit or compensate effects of evocative emotional stimuli on performance. A recent study provided evidence for this theory by showing effects of emotion on performance in WM tasks with high demands (or high load WM tasks) but not in WM tasks with low demands (or low load WM tasks) (Li, Ouyang, & Luo, 2012).
Given that empirical findings in depressed and dysphoric adolescents are scarce and mixed, and that the majority of previous work has relied on manual reaction time measures (Mueller, 2011; Vilgis, Silk, & Vance, 2015), the current study aims to extend this research by measuring the influence of emotion on WM in dysphoric adolescents with a saccadic eye movement task. Eye movement responses have the advantage of providing a precise and direct measure of cognitive control processes and are a reliable and sensitive measure in normative and clinical populations of youth (Armstrong & Olatunji, 2012; Karatekin, 2007). Furthermore, since the influence of emotional stimuli may be dependent on the cognitive demands of a task (ACT; Eysenck & Calvo, 1992; Eysenck et al., 2007), this study compared dysphoric and non-dysphoric adolescents on a high load versus low load WM task in the presence of emotional distractor stimuli. While comparable research in depressed or dysphoric adolescents is absent, a study of Mueller et al. (2015) used a similar eye movement task with negative and neutral distractor stimuli and indicated effects of emotional distractor stimuli on low load WM performance in healthy but not clinically anxious adolescents. Finally, and in contrast with a great deal of previous work on depression-related cognitive control impairments including sad emotional information (e.g., Goeleven, De Raedt, Baert, & Koster, 2006; Kyte et al., 2005; Levens & Gotlib, 2010; Maalouf et al., 2012), the current research sought to examine WM processes in response to pictures of angry faces. The specific focus on angry faces is based on the fact that these emotional stimuli are of direct personal relevance for depressed adolescents and can be associated with the depression-related schemas of social rejection (Gilboa-Schechtman, Ben-Artzi, Jeczemien, Marom, & Hermesh, 2004; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Hames, Hagan, & Joine, 2013).

Based on leading cognitive models of depression (Beck, 1976; Joormann et al., 2007; Koster et al., 2011) and a small number of studies emphasizing impaired cognitive control in response to negative emotional information in adolescent depression (Kyte et al., 2005; Ladouceur et al., 2006; Maalouf et al., 2012), we hypothesized prioritized processing of negative stimuli irrespective of cognitive demands in dysphoric adolescents. This would suggest that dysphoric adolescents show impaired WM performance in the presence of negative distractor stimuli in both the low and the high load WM condition. With regard to the non-dysphoric adolescents and based on ACT (Eysenck & Calvo, 1992; Eysenck et al., 2007), we expected that non-dysphoric adolescents would show WM impairments in the presence of emotional
distractor stimuli in the high load WM condition, but not in the low load WM condition.

Materials and Methods

Participants

Eighty-five adolescents between 10 and 18 years of age (65% female, mean age = 12.86, SD = 2.02) volunteered for this study. In order to obtain a youth sample with a broad range of depressive symptoms, non-referred (n = 64 or 75%) and referred adolescents (n = 21 or 25%) were included in the sample. Non-referred adolescents were recruited through advertising in schools or were recruited from a sample of adolescents who participated in a larger, school-based study on well-being. The referred adolescents were recruited from two clinical centers and were invited if they were referred for treatment of internalizing problems. Data of twenty participants (23%) was excluded due to technical problems, calibration issues, or tracker loss. These participants did not significantly differ from the final sample on the basis of age, intelligence, depressive symptoms, F(3, 77) = .384, p = .765, η² = .01, or gender distribution, χ² (1, 85) = 1.792, p = .181. This resulted in a final sample of 65 adolescents (69% female, mean age = 12.88, SD = 2.07; see Table 1). Based on their scores on the Children’s Depression Inventory (CDI; Kovacs, 1992; Mattison, Handford, Kales, & Goodman, 1990) at the moment of testing, participants were classified as dysphoric (CDI ≥ 11; n = 25) or non-dysphoric (CDI < 11; n = 40). In the dysphoric group (range CDI scores = 11-31), 44% were from the referred sample and 56% from the non-referred sample, whereas in the non-dysphoric group (range CDI scores = 0-10), 87.5% were from the non-referred sample and 12.5% from the referred sample. We opted for a cut-off score of 11 on the CDI since this cut-off point has been shown to have relatively good psychometric properties in predicting dysphoria in youth and is considered to represent mild levels of depression (Gold, 1993; Shemesh et al., 2005; van Beek, van Dolderen, & Dubas, 2006; Worcel et al., 1990). The research protocol was approved by the Ethical Committee of Ghent University Hospital. Youngsters signed informed assent while legal guardians signed informed consent. After completing the task and the questionnaires, participants were compensated with two cinema tickets.

Measures

Depressive symptoms. The CDI (Kovacs, 1992; Dutch version by Timbremont & Braet, 2002) is a 27-item self-report questionnaire designed to assess depressive symptoms in youth. Each item comprises three response options, which vary in severity and are rated
on a 3-point scale (e.g., “I do most things wrong”, “I do many things wrong”, “I do everything wrong”). CDI showed good psychometric qualities in terms of internal consistency and test-retest reliability in non-clinical samples (Craighead, Smucker, Craighead, & Ilardi, 1998; Timbremont & Braet, 2002). Cronbach’s alpha on the CDI in this sample was α = .84.

**Trait anxiety.** The trait version of the State-Trait Anxiety Inventory for Children (STAI-TC; Bakker, Wieringen, Ploeg, & Spielberger, 2004; Spielberger, 1973) is a 20-item self-report questionnaire that assesses the frequency and intensity of anxiety symptoms. Items are rated on a 3-point Likert scale with 1 = ‘almost never’ and ‘3’ = often. The STAI-TC is considered as a reliable and valid measure for assessing anxiety symptoms in youngsters. Internal consistency in this study was good with a Cronbach’s alpha of .86.

**Intelligence.** An intelligence score was calculated by using an abbreviated version of the Dutch Wechsler Intelligence Scale for Children III (WISC-III; Kort, 2002). This shortened version has been found to be reliable and valid (Sattler, 1992; Strauss, Sherman, Spreen, & Spreen, 2006) and consists of two subtests: Vocabulary and Block Design.

**Emotional memory-guided saccade task (MGST).**

**Overview of the task.** The emotional MGST was used to measure the influence of emotional information on WM processes (Mueller et al., 2015). In each trial, participants were required to maintain fixation to a central point while remembering the location of target stimuli that were briefly presented in the periphery. In the high load condition, the location of four different target stimuli had to be remembered, while in the low load condition, the location of two different target stimuli had to be remembered. After a short decoding/encoding phase, the target stimuli disappeared and participants were asked to make an eye movement to the remembered location of the specific target stimulus.

**Timing.** A white fixation cross was presented for 500 ms in the center of the computer screen before the start of each trial. Trial onset was indicated by the white fixation cross changing into a circle and this was followed by the appearance of target stimuli in the periphery for 1200 ms. Participants were instructed to maintain central fixation to the circle while the target stimuli were on the screen. Target stimuli were rectangles in different colors (i.e., brown, green, cyan, and magenta) and appeared in two (top right and bottom left or top left and bottom right) or all four screen corners (top left, top right, bottom left, bottom right). Next, the peripheral target stimuli disappeared and
participants continued to maintain central fixation (between 2000 and 3000 ms). Then, the color of the central fixation circle changed into one of two or four target stimuli colors for 300 ms (imperative cue) and participants were asked to make an eye movement to the quadrant or corner in which the target stimulus in the depicted color had been presented.

**Trial types.** Improving on the previous design by Mueller et al. (2015), which did not assess baseline performance, participants started first with a non-emotional baseline version and then completed an emotional version of the MGST. In the *baseline version*, the target stimuli (colored rectangles) appeared in two diagonally-opposite screen corners and did not include emotional information. In the *emotional version*, however, the colored rectangles were overlaid with irrelevant affective stimuli. Also improving on the previous study, which only had two emotions, here three emotions were included, namely, neutral, angry, and happy faces. Importantly, in a given trial, all colored rectangles were overlaid with the same emotional face (i.e. same identity and same emotional expression). The order of which identity was paired with which emotional expression was randomized from trial to trial. The emotional version included both low load and high load trials. In *low load trials* participants had to remember the location of two target stimuli, whereas in the *high load trials* participants had to remember the location of four target stimuli. Finally, to ensure that participants maintained central fixation during the presentation of the peripheral target stimuli, 28 catch trials were added to the task. *Catch trials* are similar to the low load and high load trials but lack an decoding/encoding phase. During these catch trials, the color of the fixation circle immediately changed into one of the target colors, preventing the decoding or encoding process. Gazing away during these randomly occurring trials resulted in an inability to respond correctly and thus, including these kind of trials stimulated participants to maintain central fixation throughout the task (cf. Mueller et al., 2015; see Figure 1).

**Stimuli.** The emotional faces were selected from the NimStim database (Tottenham et al., 2009). The final stimulus set included pictures of 16 actors (8 female), each posing a neutral, angry, and happy facial expression. This generated six trial types: low and high load trials of either neutral, angry, or happy valence. The baseline version consisted of 30 trials, whereas the emotional version consisted of 264 trials, including 111 low load trials (37 for each emotion), 111 high load trials (37 for each emotion), and 42 catch trials (21 low load/21 high load).

**Eye movement recordings.** Eye movements were recorded with a Tobii TX-300 eyetracker system (Danderyd, Sweden). Saccades were defined as eye movements that
were greater than 30°/s and that lasted at least 50ms and were analyzed offline with a custom script in R. Saccade latency was indexed as the interval between the imperative cue onset and the saccade onset to one of the four screen corners. Saccade latencies were excluded from further analyses if they were faster than 80 ms or slower than 2000 ms. Saccade accuracy was determined as the percentage of eye movements directed to the correct corner.

Figure 1. (A) Design of a baseline trial. (B) Design of a high load (left half of panel B) and a low load (right half of panel B) trials. (C) Design of a catch trial for high load (left half of panel C) and low load trials (right half of panel C). The white arrow indicated the correct direction where the eye movement response should have been, but this arrow did not appear in the task.

Procedure

Participants were invited to the lab at the Faculty of Psychology and Educational Sciences. After signing assent/consent, written and oral task instructions were given by the experimenter. Prior to the start of the experiment, all participants performed some practice trials (on paper) together with the experimenter to ensure comprehension of the instructions. In order to improve motivation of young adolescents to complete the MGST, participants were told that it was a game in which they could train their “spy” skills by observing and memorizing stimuli without directly looking at them. After finishing the
MGST, all participants completed the Vocabulary and Block Design test of the WISC-III. At the end of the experiment, subjects completed the CDI and the STAI-TC. This order of testing prevents priming effects caused by self-report questionnaires and ensures that the intelligence test or questionnaires do not tire or overwhelm participants before starting the MGST.

**Data Analyses**

A repeated-measures analysis of covariance (rmANCOVA) with Load (High, Low) and Emotion (Angry, Happy, Neutral) as within-subjects factor and Group (Dysphoric, Non-dysphoric) as between-subjects factor was conducted for latency and accuracy (% correct) data, separately. Age and intelligence score of the participants were included as standard covariates of no interest in all analyses. In addition, and to control for baseline WM performance, mean of median RTs and mean accuracy rates of the baseline task were also included as a covariate of no interest, in the latency and accuracy analyses, respectively. In a second round of analyses, also STAI-TC scores were added as covariates of no interest to explore the impact of anxiety symptoms on the findings. Finally, to assess the contribution of symptom severity, correlation analyses were performed between CDI and STAI-TC scores and the different performance variables. Effects sizes are provided as eta squared ($\eta^2$) and Cohen’s $d$, as appropriate. Alpha was set at $p = 0.05$, two-tailed. Analogous to previous eye movement studies (Mueller, Jackson, Dhall, Datsopoulos, & Hollis, 2006; Mueller et al., 2015), mean of median RT data were used in the latency analyses to account for skewness of the data commonly found with saccades and to reduce the influence of outliers. For every participant, trials with incorrect responses were removed for the latency analyses. Accuracy data were calculated as the percentage of correct trials. Catch trials were excluded from analyses, since they merely served as trials to ensure central fixation.

**Results**

**Group Characteristics**

As expected, dysphoric youths, relative to non-dysphoric youths, had significantly more depressive symptoms, $F(1, 64) = 85.93, p < .001, \eta^2 = .58$, and anxiety symptoms, $F(1, 58) = 15.68, p < .001, \eta^2 = .22$, but a lower intelligence score, $F(1, 58) = 4.83, p = .03, \eta^2 = .08$. There were no age, $F(1, 64) = 3.10, p = .083, \eta^2 = .05$, or gender differences, $\chi^2 (1, 65) = 2.21, p = .137$ (Table 1).
Table 1

Characteristics of the sample

<table>
<thead>
<tr>
<th></th>
<th>Depressed</th>
<th>Non-depressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>25</td>
<td>40</td>
</tr>
<tr>
<td>Depressive symptoms***</td>
<td>16.28 (5.80)</td>
<td>6.32 (2.82)</td>
</tr>
<tr>
<td>Anxiety symptoms ***</td>
<td>40.61 (7.01)</td>
<td>33.24 (6.85)</td>
</tr>
<tr>
<td>Age</td>
<td>13.44 (2.06)</td>
<td>12.52 (2.02)</td>
</tr>
<tr>
<td>Intelligence ***</td>
<td>17.90 (4.23)</td>
<td>20.71 (5.04)</td>
</tr>
<tr>
<td>Sex (female/male)</td>
<td>20/5</td>
<td>25/15</td>
</tr>
</tbody>
</table>

Note. *p < .05; **p ≤ .01; *** p < .001. Intelligence = An intelligence score was calculated by summing the standard scores on Vocabulary and Block design for each participant. Standard deviations are in parentheses.

Latency Analyses

The results of the rmANCOVA with Load (High, Low) and Emotion (Angry, Happy, Neutral) as within-factors and Group (dysphoric, non-dysphoric) as between-subject factor indicated no main effects of Load, $F(1, 51) = .204, p = .653, \eta^2 = .002$, or Emotion, $F(2, 102) = .537, p = .586, \eta^2 = .002$. Interestingly, a significant three-way interaction between Load, Emotion, and Group emerged, $F(1.994, 101.684) = 3.36, p = .039, \eta^2 = .02$. To explore this result, a Load by Emotion ANOVA was run for dysphoric and non-dysphoric adolescents separately. The findings indicated a main effect of Load in the dysphoric group, $F(1, 24) = 75.18, p < .001, \eta^2 = .55$, and the non-dysphoric group, $F(1, 39) = 107.22, p < .001, \eta^2 = .55$. In the dysphoric group, the Load by Emotion interaction was not significant, $F(2, 48) = .734, p = .485, \eta^2 = .005$. In the non-dysphoric group, however, the Load by Emotion interaction was statistically significant, $F(2, 78) = 7.48, p = .001, \eta^2 = .02$. Follow-up paired samples t-tests showed that in the high load condition, latencies were slower for angry faces compared to happy faces, $t(39) = 2.03, p = .049, d = .19$, and neutral faces, $t(39) = 3.24, p = .002, d = .35$. Latencies did not differ between happy and neutral faces, $t(39) = 1.61, p = .114, d = .15$. In the low load condition, no differences emerged between angry, happy, or neutral faces (all $ps > .10$) (see Figure 2).
Accuracy Analyses

The results of the rmANCOVA on the accuracy data revealed a main effect of Load, $F(1, 51) = 17.71, p < .001, \eta^2 = .11$, indicating lower accuracy rates in the high load condition relative to the low load condition. Furthermore, a significant interaction was found between Load and age, $F(1, 51) = 11.56, p = .001, \eta^2 = .07$, and Load and intelligence score, $F(1, 51) = 7.28, p = .009, \eta^2 = .05$. Follow-up analyses showed a smaller difference in accuracy rates between the high load and the low load condition with increasing age, $r(63) = -.35, p = .005$, and increasing intelligence, $r(58) = -.27, p = .038$. In addition, a significant Load by Group interaction was found, $F(1, 51) = 4.28, p = .044, \eta^2 = .03$, indicating a larger difference in accuracy rates between the high load and the low load condition in the dysphoric group compared to the non-dysphoric group, $F(1, 51) = 4.17, p = .046, \eta^2 = .06$. Finally, the results also revealed an Emotion by Group interaction, $F(2, 102) = 4.05, p = .02, \eta^2 = .01$. Within-group comparisons indicated that in the dysphoric group, accuracy rates were lower for happy distractor faces compared to angry distractor faces, $t(24) = -2.26, p = .03, d = .23$. No differences were found between happy and neutral faces, or between angry and neutral faces (all $ps > .14$). In the non-dysphoric group, accuracy rates were higher for happy faces relative to neutral faces, $t(39) = 2.74, p = .009, d = .26$, and angry faces, $t(39) = 3.48, p = .001, d = .29$. No differences emerged between accuracy rates for angry and neutral faces, $t(39) = -.541, p = .591, d = .06$. Finally, between-group analyses showed higher accuracy rates in the non-dysphoric relative to the dysphoric group, but only for happy faces, $t(63) = 2.21, p = .03, d = .55$ (see Figure 3).

Additional Analyses of Comorbid Anxiety Symptoms and Symptom Severity

All analyses were rerun to examine the impact of comorbid anxiety symptoms on the latency and accuracy data. For the latency analyses, results indicated that the three-way interaction among Load, Emotion, and Group remained significant, $F(2, 92) = 4.18, p = .018, \eta^2 = .02$. Moreover, anxiety symptoms did not interact with the within-subject factors (all $ps > .14$). For the accuracy analyses however, the Load by Group and the Emotion by Group interactions disappeared (all $ps > .063$). Finally, CDI and STAI-TC scores were not significantly correlated with the different performance variables (all $ps > .58$, corrected for multiple comparisons).
**Figure 2.** *p < .05; **p < .01. Latencies (ms) for dysphoric adolescents (left panel) and non-dysphoric adolescents (right panel). Baseline = baseline condition (i.e., 2 target stimuli without emotional distractors); Low = low load condition (i.e., 2 target stimuli with emotional distractors); High = high load condition (i.e., 4 target stimuli with emotional distractors). Angry = trials with angry distractor faces; Happy = trials with happy distractor faces; Neutral = trials with neutral distractor faces. Error bars represent standard error of the mean.
Figure 3. $p < .05$; **$p < .01$. Accuracy rates (percentage correct) for dysphoric adolescents and non-dysphoric adolescents. Baseline = baseline condition. (i.e., trials without emotional distractors); Angry = trials with angry distractor faces; Happy = trials with happy distractor faces; Neutral = trials with neutral distractor faces. Error bars represent standard error of the mean.
Discussion

The current study assessed to what extend dysphoric youth have a biased attention towards emotional stimuli during cognitive control, here assessed by a WM task. Based on cognitive theories of depression (Beck, 1976; Joormann et al., 2007; Koster et al., 2011) and limited evidence regarding the deleterious impact of negative emotional information on cognitive control in adolescent depression (Kyte et al., 2005; Ladouceur et al., 2006; Maalouf et al., 2012), we expected WM impairments in the context of negative emotional stimuli in both the low and the high load WM condition.

Contrary to expectations, in the latency data, WM performance was unaffected by irrelevant emotional stimuli in dysphoric adolescents. Specifically, they were not influenced by the presence of angry, happy, or neutral distractor faces. By contrast, in non-dysphoric adolescents, negative emotional stimuli interfered with WM performance but only under high cognitive demands. Here, angry distractor faces compared to happy and neutral distractor faces slowed saccade latencies in the high load WM condition. Of note, these results on latency remained unchanged when controlling for comorbid anxiety symptoms. Effects of emotion became more apparent in the accuracy analyses, where irrelevant positive stimuli interfered with WM performance in dysphoric adolescents. Specifically, accuracy rates of the dysphoric group were lower in the presence of happy distractor faces compared to angry distractor faces. In non-dysphoric adolescents, however, positive stimuli improved WM performance, by which happy distractor faces led to higher accuracy rates compared to angry and neutral distractor faces and in comparison with the dysphoric group. Importantly though, these effects of emotion on accuracy rates disappeared after controlling for comorbid anxiety symptoms.

The present findings in the saccade latencies may point to a lower reactivity to emotional stimuli during cognitive control in dysphoric compared to non-dysphoric adolescents. These results support the Emotion Context Insensitivity (ECI) model of depression (Rottenberg, Gross, & Gotlib, 2005), which postulates that depression is characterized by alterations in the amygdala-prefrontal cortex connectivity and a blunted emotional reactivity to both positive and negative stimuli. Drawing on evolutionary theories (Nesse, 2000), the EIC model assumes that a depressed mood state may have originally evolved as a defensive response in adverse circumstances and provokes chronic inactivity and a reduced reactivity to novel emotional stimuli in particular. Supportive evidence for this model has already been obtained in several behavioral, physiological,
and neuroimaging studies on emotional reactivity in depressed adults (e.g., Dichter & Tornarken, 2008; Foti, Olvet, Klein, & Hajcak, 2010; Rottenberg et al., 2005). Interestingly, our findings are further in line with an eye tracking study of Ellis, Beevers, and Wells (2011), which indicated an attentional bias towards emotional information in non-dysphoric students, but not in dysphoric students.

In addition, the current latency results indicate that, within the context of WM, non-dysphoric adolescents exhibit a bias towards angry distractor faces. This confirms the “threat relevance framework” and related studies which state that individuals show a tendency to orient towards threat-relevant information, such as snakes and angry facial expressions, to evaluate the level of danger (e.g., Kindt, van den Hout, de Jong, & Hoekzema, 2000; Lobue & DeLoache, 2008; Ohman & Mineka, 2001). Interestingly, angry faces only slowed their performance in the high load WM condition. This accords with theory and research suggesting that, especially when cognitive demands are high and processing resources are limited, individuals experience difficulties filtering irrelevant emotional information during cognitive tasks (Eysenck & Calvo, 1992; Eysenck et al., 2007; Li et al., 2012).

In the accuracy data, happy distractor faces, as compared to angry distractor faces, impaired WM performance in dysphoric adolescents. These results are similar to those obtained in a study of Derakshan, Salt, and Koster (2009) using a saccadic eye movement task in dysphoric students and indicate that positive stimuli cause more interference during WM processing as compared to negative stimuli in dysphoric youth. A potential explanation for this result is that happy faces are mood-incongruent and unfamiliar to them and therefore cause increased error rates on a WM task (Demenescu et al., 2011). In contrast, happy distractor faces improved WM performance in non-dysphoric adolescents. This result indicates that happy faces have a beneficial effect on their WM performance and is congruent with prior research showing a positive memory effect in healthy individuals (e.g., Cromheeke & Mueller, 2015; D'Argembeau & Van der Linden, 2007; Hamilton & Gotlib, 2008). However, it should be acknowledged that these findings disappeared when comorbid anxiety was taken into consideration suggesting that the interaction between group (dysphoric, non-dysphoric) and emotion of the distractor faces (happy, angry, neutral) on accuracy data may have been driven by comorbid anxiety symptoms.

Importantly, the findings from our saccadic WM task are incompatible with recent cognitive theories (Joormann et al., 2007; Koster et al., 2011) and contradict a number of
studies in pediatric samples, which reported a detrimental effect of negative emotion on cognitive control processing in depressed youth (for a review see Mueller, 2011; Vilgis et al., 2015). These diverging results might be explained by *sample characteristics*. Specifically, while previous studies focused on adolescents diagnosed with major depressive disorder (Kyte et al., 2005; Ladouceur et al., 2006; Ladouceur et al., 2005; Maalouf et al., 2012), the current study focused on adolescents with mild depressive symptoms or dysphoria. It can thus be hypothesized that cognitive resources to inhibit the processing of emotional interfering stimuli significantly diminish with increasing depressive severity (De Raedt & Koster, 2010). Furthermore, the discrepancy may also be associated with *stimulus-specific differences*. For instance, several studies used verbal stimuli (Kyte et al., 2005; Maalouf et al., 2012) or background scenes (Ladouceur et al., 2005), which cover a wide range of negative emotions (i.e., sadness, anger, fear), whereas the current study used specific facial expressions as emotional stimuli. It may be that the impact of an emotionally-laden stimulus on cognitive control performance depends on its intensity and relevance to depressed or dysphoric adolescents (Pessoa, 2009; Rottenberg et al., 2005).

Further, the current study results are inconsistent to a memory-guided saccade study of Mueller et al. (2015) in pediatric anxiety, which found that healthy, but not anxious youth, experienced an effect of threatening stimuli in the *low load* WM condition. These results are concordant with limited resources theories, which state that emotional stimuli will only impair WM performance when task demands are low and sufficient processing resources are available (Bishop, 2007; Pessoa, 2009). However, they are incongruent to the present findings in which healthy youth only showed a bias towards emotion in the *high load* WM condition. A couple of task-related differences may explain this discrepancy. First, in contrast to Mueller et al. (2015) who only explored the effects of negative and neutral information on WM performance, the MGST used in the current study included positive, negative, and neutral distractor stimuli. Adding positive stimuli to the paradigm improves interpretation and generalizability of the results as neutral and negative stimuli are easily confused or misinterpreted (Whalen, 1998). In addition, the present study adapted and improved the paradigm of Mueller et al. (2015) by adding a non-emotional baseline condition, which enables the consideration of baseline cognitive control processes.

The findings bear several clinically-relevant implications. The low reactivity to emotional distractor stimuli and unaffected WM performance of dysphoric adolescents can
be framed within the “mental inflexibility view”. According to this view, the typical tendency of depressed or dysphoric individuals to become stuck cognitively (i.e. rumination) and affectively (i.e. emotional inertia) may counterintuitively be associated with successful performance in cognitive control tasks that require active goal maintenance (e.g., remember location of colored rectangles) despite the presence of task-irrelevant emotional stimuli (e.g., distracting emotional faces; Altamirano et al., 2010; Koval, Kuppens, Allen, & Sheeber, 2012). Importantly, this inflexibility may hinder emotion regulation (ER), as it is postulated that adequate ER requires adaptive behavior in a rapidly changing (emotional) environment (Aldao, Sheppes, & Gross, 2015; Keltner & Gross, 1999). Hence, in light of future prevention and early intervention, a promising avenue for future research is to explore the effects of a training targeted at emotional awareness and attentional flexibility on emotion regulation (ER) in dysphoric adolescents. Emotional awareness refers to attention for emotions and emotional experiences, as well as emotional differentiation and identification (Ciarrochi, Heaven, & Supavadeeprasit, 2008; Lambie & Marcel, 2002), and training this ability has already been discussed a promising component of prevention programs and psychotherapy for disorders such as depression, anxiety, and borderline personality disorder (Dozois, Seeds, & Collins, 2009; Farrell & Shaw, 1994; Kranzler et al., 2016). Further, with respect to attentional flexibility, a review of Wadlinger and Isaacowitz (2011) indicated that flexible attentional allocation towards positive and negative affect can be trained through extensive practice and demonstrated positive effects of various attentional training programs on individuals’ ER ability.

Several limitations should be noted. First, although the current results are consistent with former research (Ellis et al., 2011; Rottenberg et al., 2005), they have to be interpreted with caution due to the relatively small sample size. Second, in contrast to previous studies that focused on cognitive control over sad (pictorial or verbal) stimuli (e.g., Kyte et al., 2005; Ladouceur et al., 2006; Maalouf et al., 2012), the current study investigated the effect of angry faces on WM in dysphoric adolescents. Since sad faces were not included in our stimulus set, we could not compare the effects of different types of negative stimuli on WM performance. Further, as depressive symptomatology was measured dimensionally by means of a self-report questionnaire, it was impossible to make reliable conclusions regarding the influence of emotion on WM in adolescents diagnosed with a major depressive disorder. Importantly, however, the present investigation included dysphoric adolescents with a wide range of depressive symptoms and indicated no
significant influence of depression severity on performance variables. Finally, the current study is limited by the cross-sectional nature of its design. Future prospective studies within at-risk adolescents are needed to replicate the current study and to explore whether altered effects of emotion on WM prospectively lead to the development of a depressive disorder.

**Conclusions**

The current study demonstrates that dysphoria is associated with diminished attention for emotional information in the context of WM and provides evidence for the EIC model of depression (Rottenberg et al., 2005). Specifically, response latencies of non-dysphoric adolescents were slower in the presence of negative distractor stimuli, whereas latencies of dysphoric adolescents were not influenced by emotional distractor stimuli. The present findings indicate altered cognitive control-emotion interactions in dysphoric youth and point to the potential importance of developing an training targeted at emotional awareness and attentional flexibility for youth at risk for developing depression.
Acknowledgements

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References


CHAPTER 4


Abstract

Cognitive theories emphasize the importance of attentional biases in the development and maintenance of depression. Noteworthy, recent studies indicate that depression-related biases only occur in later stages of attentional processing. This is consistent with the idea that attention is a multicomponent process, consisting of at least two mechanisms: selection and inhibition. Therefore, this study aims to investigate interference and inhibition towards angry and happy stimuli in dysphoric adolescents compared to non-dysphoric adolescents. To examine interference and inhibition of emotional information in 21 dysphoric (17 girls) and 28 non-dysphoric adolescents (17 girls), 10-16 years of age, a Negative Affective Priming task was used. In this task, a target has to be evaluated as positive or negative while ignoring a distractor. As expected, dysphoric adolescents showed both higher interference from and higher inhibition of angry stimuli relative to non-dysphoric adolescents. In contrast, happy stimuli did not lead to interference and consequently did not have to be inhibited in either group. Finally, a positive relation was found between interference and the subsequent inhibition of emotional stimuli. These observations confirm the existence of a bias towards angry faces in dysphoric adolescents and also indicate a higher inhibition of angry faces in dysphoric adolescents compared to non-dysphoric adolescents. The obtained results are different.

from those of similar previous studies in depressed or dysphoric adults using sad faces or negatively valenced words and might reveal important emotion-specific or age-specific inhibitory biases.
Introduction

In general, cognitive theories assign a crucial role to information processing biases in the etiology and persistence of depression (Beck, 1976; Clark, Beck, & Alford, 1999). More specifically, Beck’s cognitive model emphasizes the importance of depressogenic self-referent schemas, which operate beyond one’s awareness and affect information processing substantially (Beck, 1976). Previous studies on depressed or dysphoric youngsters support the existence of negative biases in different aspects of information processing in this age group, indicating a better memory for negative information (Neshat-Doost, Taghavi, Moradi, Yule, & Dalgleish, 1998; Timbremont, Braet, Bosmans, & Van Vlierberghe, 2008) and an attentional bias for negative, mood-congruent information (Gibb, Benas, Grassia, & McGeeary, 2009; Hankin, Gibb, Abela, & Flory, 2010). However, empirical support for the latter finding in depressed individuals is not straightforward. Specifically, results only support depression-related attentional biases under conditions of long stimulus exposure, whereas no attentional bias was found in early “automatic” processes (e.g., Mogg & Bradley, 2005; Neshat-Doost, Taghavi, Moradi, Yule, & Dalgleish, 1997; Peckham, McHugh, & Otto, 2010).

An important variable, which may account for these inconclusive results, is the conceptualization of attention either as a single process or as a set of distinct processes (e.g., Houghton & Tipper, 1994; Neumann & Deschepper, 1992). Depressed individuals might experience particular difficulties disengaging or releasing attention from distracting negative stimuli rather than having problems attending to them and thus only show biases in more elaborative stages of attentional processing (De Raedt & Koster, 2010). Therefore, it is generally assumed that selective attention cannot be viewed as a unitary construct but, rather, a construct that involves at least two underlying processes: active selection of relevant information (e.g., a target stimulus that has to be attended) and inhibition of irrelevant information (e.g., flankers surrounding the target) (Hasher & Zacks, 1988; Milliken & Tipper, 1998). This dual process of selective attention facilitates responses to relevant to-be-selected stimuli and slows responses to irrelevant stimuli (Gotlib, Yue, & Joormann, 2005; Milliken, Tipper, & Weaver, 1994). During the selection of relevant stimuli, attention can be disrupted by distracting stimuli and therefore requires active inhibition of irrelevant information in order to reduce this interference (Tipper, 1985; Tipper & Cranston, 1985). Moreover, inhibition is responsive to interference, which indicates that the more interference a distractor causes, the more it has to be inhibited (e.g.,
Goeleven, De Raedt, & Dierckx, 2010; Malley & Strayer, 1995; Milliken et al., 1994). Yet, until now, the effect of emotional distractors on both attentional processes in depressed or dysphoric youngsters remains unclear. Given the crucial role of information processing in the etiology of depression, it is therefore important to study these different attentional components in depth.

Two paradigms that have been extensively used to study attentional processing of emotionally valenced stimuli include the emotional Stroop task and the dot probe task (Mogg & Bradley, 2005; Peckham et al., 2010). Although popular, the abovementioned paradigms only provide a rough measurement of attentional processes since relevant and irrelevant information are presented within the same stimulus presentation (Mogg & Bradley, 2005). It is noteworthy that recent studies in depressed individuals have examined elaborated attentional processing by using more advanced visual attention tasks, such as the exogenous cueing task (e.g., Leyman, De Raedt, Schacht, & Koster, 2007), the affective go/no-go task (e.g., Kyte, Goodyer, & Sahakian, 2005) or the antisaccadic eye movement task (e.g., Hardin, Schroth, Pine, & Ernst, 2007; Sweeney, Strojwas, Mann, & Thase, 1998). Results of these studies offered further evidence for maintained attention for negative information compared to neutral information under conditions of long stimulus exposure (Koster, De Raedt, Goeleven, Franck, & Crombez, 2005; Leyman et al., 2007) and for impaired inhibition of irrelevant stimuli in depressed adolescents and adults (Hardin et al., 2007; Sweeney et al., 1998). It is important to note, however, these paradigms cannot investigate impairments on the level of both selective and inhibitory attentional processes.

To date, only a few studies have used negative affective priming (NAP) tasks that are able to map the process of interference and subsequent inhibition in depressed and dysphoric adults (Goeleven, De Raedt, Baert, & Koster, 2006; Gotlib et al., 2005; Joormann, 2004; Joormann & D'Avanzato, 2010; Zetsche & Joormann, 2011). In these multi-stimulus tasks, participants are asked to respond to a target stimulus, while ignoring a simultaneously presented emotional distractor stimulus. In the next display, the target may have the same valence as the previous distractor stimulus. Inhibition can be indexed by the degree to which responding to a novel target stimulus is delayed by a previous distractor having the same emotional valence (Wentura, 1999). Results of these studies have yielded mixed results. First, Gotlib et al. (2005) used an adapted version of the NAP task with emotionally valenced words to investigate both affective interference and inhibition. In this task, a target and a distractor were presented simultaneously in each
display and participants were asked to name aloud the target word while ignoring the distractor. Results indicated both a higher interference from and a higher inhibition of negative distractors in dysphoric students. These findings were confirmed in a pictorial NAP study of Zetsche and Joormann (2011), who found that depressive symptoms were associated with a higher inhibition of angry faces. However, other researchers using the NAP task in depressed and dysphoric participants (Goeleven et al., 2006; Joormann, 2004) provided evidence for a lower inhibition of sad facial expressions and negative words. Because the focus of these studies was mainly on inhibitory functioning, the level of interference and the association between interference and inhibition of emotional stimuli were not studied (Goeleven et al., 2006; Joormann, 2004; Joormann & Gotlib, 2010). Moreover, until now, studies examining the contribution of each of these two processes in adolescents are, to our knowledge, nonexistent.

Given the limited and mixed results, the aim of the present study was to examine different levels of attentional functioning in dysphoric adolescents. Since it is stated that cognitive biases play a key role in the development of depression (Beck, 1976), it is highly relevant to study different attentional processes in dysphoric or at-risk groups before a full-blown depression occurs. Moreover, adolescents are an interesting subject group, as adolescence represents a particularly vulnerable period for the development of depressive symptoms (Dahl, 2004). For instance, dysphoric adolescents face a twofold to threefold higher risk of major depression in adulthood relative to adult onset depression (Pine, Cohen, Cohen, & Brook, 1999; Pine, Cohen, Gurley, Brook, & Ma, 1998), with a more severe disease progression (Hankin et al., 1998; Lewinsohn, Rohde, Seeley, Klein, & Gotlib, 2000). Part of this increased vulnerability can be found in ongoing brain development that is characterized by an imbalance between an early maturation of subcortical “affective” regions, such as the amygdala, and a late maturation of prefrontal cortical regions involved in cognitive control processes (Ernst, Pine, & Hardin, 2006).

Against this background, our purpose was to examine interference and inhibition towards negative stimuli in dysphoric youngsters, with the use of a NAP paradigm. Clearly, past research on depression-related attentional biases either has used a broad range of positively and negatively valenced words (e.g., Joormann, 2004; Joormann & D'Avanzato, 2010; Kyte et al., 2005) or has relied on sad faces (e.g., Goeleven et al., 2006; Joormann, Talbot, & Gotlib, 2007). Based on previous notions that faces are more ecologically valid and stronger than verbal stimuli (Bradley et al., 1997), our research sought to examine attentional processes in response to emotional faces. However, in
contrast to previous studies (e.g., Goeleven et al., 2006; Goeleven et al., 2010), we decided not to use sad faces as these stimuli are mood-congruent and familiar to dysphoric youngsters. Instead, we opted for angry faces because these kind of emotional stimuli are thought of bearing direct personal relevance to adolescents suffering from depressive symptoms and can be associated with the depression-related schemas of social rejection (Gilboa-Schechtman, Ben-Artzi, Jeczemien, Marom, & Hermesh, 2004; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Hames, Hagan, & Joine, 2013). According to interpersonal theories of depression, depressed individuals engage in inappropriate social behaviors that are likely to elicit social rejection, which in turn confirms negative schemas and increases depressive symptoms (Coyne, 1976; Joiner, Alfano, & Metalsky, 1992). Although a bias towards threatening stimuli has often been studied in anxious youth and adults (e.g., Lau & Pine, 2008; Mogg, Bradley, Williams, & Mathews, 1993; Mogg, Philippot, & Bradley, 2004), a few studies in depressed samples have already used angry facial expressions (e.g., Koster, Leyman, De Raedt, & Crombez, 2006; Leyman et al., 2007; Neshat-Doost, Moradi, Taghavi, Yule, & Dalgleish, 2000; Zetsche & Joormann, 2011). Some of these studies provided evidence for an attentional bias towards angry faces in depressed adults (Leyman et al., 2007) and comorbid anxious depressed adolescents (Hankin et al., 2010), whereas others failed to find this bias (e.g., Koster et al., 2006; Neshat-Doost et al., 2000).

Drawing on cognitive theories of depression (Beck, 1976) and the results of studies measuring attentional interference of emotional stimuli in depressed and dysphoric individuals (Gotlib et al., 2005; Hankin et al., 2010; Joormann & Gotlib, 2007; Leyman et al., 2007; Siegle, Ingram, & Matt, 2002), we predict that, relative to healthy controls, dysphoric adolescents will show more interference in the presence of angry compared to happy distractors. With regard to inhibition, based on prior conflicting evidence, two different hypotheses can be proposed. On the one hand, studies using a NAP task with sad faces or negative words in depressed and dysphoric adults (e.g., Goeleven et al., 2006; Joormann, 2004) would suggest a lower inhibition of angry faces in the dysphoric group, i.e. no slowdown or a faster response to negative probe targets in the experimental condition (as compared to the control condition). On the other hand, other studies using similar experimental designs including angry faces or negative words in dysphoric adults (e.g., Gotlib et al., 2005; Zetsche & Joormann, 2011) would suggest a higher inhibition of angry faces in the dysphoric group, i.e., a slower response to negative probe targets in the experimental condition (compared to the control condition). The latter would be in line
with the idea that a higher interference of social rejection stimuli is associated with a higher inhibition of those stimuli in dysphoric youngsters (Milliken et al., 1994; Zetsche & Joormann, 2011).

Methods

Participants

Seventy-four Dutch-speaking adolescents between 10 and 16 years of age, including 40 referred adolescents for treatment of emotional problems (28 girls; mean age = 13.57, \(SD = 1.65\)) and 34 non-referred, healthy adolescents (21 girls; mean age = 12.76, \(SD = 1.28\)), participated. In the non-referred group, healthy adolescents were recruited through advertising in schools. To have a refined dysphoric and non-dysphoric group, all participants with a score below the subclinical cut-off score on Children’s Depression Inventory (CDI; < 13) in the referred group and those with a score above or equal to this cut-off score (\(\geq 13\)) in the non-referred group were excluded from the analyses (Kovacs, 1992). This resulted in a final sample consisting of 21 adolescents with dysphoria (17 girls; mean age = 12.78, \(SD = 1.23\)) and 28 adolescents without dysphoria (17 girls; mean age = 13.86, \(SD = 1.56\)). The research protocol was approved by the Ethics Committee of the University Hospital. Youngsters signed informed assent while legal guardians signed informed consent. After completing the questionnaires and the task, participants were compensated with two cinema tickets.

Measures

Depressive symptoms. A Dutch version of the CDI (Kovacs, 1992; Dutch version by Timbremont & Braet, 2002) was used to assess depressive symptoms. The CDI is a self-report questionnaire derived from the Beck Depression Inventory (BDI; Beck, Ward, Mendelsohn, Mock, & Erbaugh, 1961) and is used in children and adolescents 7-17 years of age. It consists of 27 items, which assesses cognitive, affective, and behavioral symptoms of depression. Each item has three response options, which vary in severity (e.g., “I do most things wrong”, “I do many things wrong”, “I do everything wrong”). Adolescents are asked to select the statement that best describes how they have been feeling during the past two weeks. A total depression score consists of the sum of all individual items. CDI showed good psychometric qualities in terms of internal consistency and test-retest reliability in non-clinical samples (Craighead, Smucker, Craighead, & Ilardi, 1998; Timbremont & Braet, 2002). Cronbach’s alpha on the CDI in this sample was \(\alpha = .90\).
**General psychopathology.** The Child Behavior Checklist (CBCL) is a parent-report questionnaire measuring emotional and behavioral problems in children and adolescent aged 6-18 years of age (Achenbach & Rescorla, 2001; Dutch version by Verhulst, Ende, & Koot, 1996). It consists of 113 items, which are scored on a 3-point scale and represent eight syndromes of psychopathology. The scores on these syndrome scales can be summed up to calculate a dimensional score for internalizing problems, externalizing problems, and total problems. Additionally, *Diagnostic and Statistical Manual of Mental Disorders (DSM)*-oriented scales can be computed measuring affective problems, anxiety problems, somatic problems, attention-deficit/hyperactivity problems, oppositional problems, and conduct problems. These scales appear to be a valid and reliable screening measure for *DSM-IV* disorders (Achenbach & Rescorla, 2001; Nakamura, Ebesutani, Bernstein, & Chorpita, 2009). In this study, the CBCL Total Problem scale and the *DSM*-oriented scale for anxiety problems were used. Internal consistency for the CBCL Total Problems scale and the CBCL Anxiety subscale was good with a Cronbach’s alpha of .97 and .71, respectively.

**Experimental Task**

**Inhibitory control.** A NAP task was used to measure the adolescents’ capacity to selectively attend to stimuli while ignoring distracting emotional information. To explore the interference and the subsequent inhibition of irrelevant emotional distractors, each trial included a pair of prime and probe displays (Joormann, 2004). It is noteworthy that participants cannot notice any differences between these displays since both prime and probe displays consist of a distractor (e.g., picture with gray frame) and a target (e.g., picture with black frame). On each display, participants are instructed to evaluate the target as positive or negative, while ignoring (inhibiting) the distractor.

Because *interference* occurs during the selection process and is generally measured in tasks in which participants are asked to respond to a target stimulus in the presence of a distractor stimulus (Goeleven et al., 2010), the prime displays are used to target this process. The control condition, in which the target and the simultaneously presented distractor stimulus share the same valence, is compared to the experimental condition, in which the valence between target and distractor is different. If attention is interfered by the simultaneous presence of an incongruent emotional distractor, responding to the target in the experimental condition will be delayed and reaction times will be slower compared to the control condition.
To measure the *inhibition* of irrelevant emotional stimuli, both prime and probe displays are taken into account. Specifically, the correspondence between the distractor in the prime display and the target in the subsequent probe display has to be considered. In the experimental condition, the valence of the distractor in the prime display is similar to the valence of the target in the probe display. Experimental trials are compared to control trials in which there is no such similarity between prime distractor and probe target. If the inhibition of (the valence) of the prime distractor is still activated, responses to a probe target of the same valence will be delayed in the experimental condition. Thus, the more inhibition of an emotionally valenced distractor, the longer the response time in the experimental condition compared to the control condition (Joormann & D'Avanzato, 2010). Of importance, to exclude interference effects on probe displays, the distractor is always a neutral face. Table 1 gives an overview of the NAP task design.

The NAP task was programmed using the INQUISIT Millisecond software package and was run on a laptop with a 72-Hz, 17-inch color monitor (Goeleven et al., 2006). The pictorial stimuli were selected from two validated databases: a recently developed database of child face images (Verfaillie, Theuwis, & Wante, 2012) and the 10 child faces of the Radboud Faces Database (Langner et al., 2010). The final stimulus set included neutral faces (*n* = 22), positive faces (happy; *n* = 33), and negative faces (angry; *n* = 33). The pictures were set at 180 x 200 pixels, and a black or gray colored frame was added to indicate if they were a distractor or a target. To exclude “feature-based” negative priming effects, eight separate lists of 11 randomly chosen pictures sharing the same valence were used: one angry and one happy prime target list, one angry and one happy prime distractor list, one angry and one happy probe target list, and two neutral probe distractor lists.

Participants were told that two pictures of different child faces would appear in the top and bottom half of the screen. They were asked to evaluate the emotional valence of the target picture -indicated by a specific color of the frame (either black or gray)- as accurately as possible by pressing the corresponding key on the response box (green button or blue button) using the index finger of each hand. In addition, they had to ignore the distractor stimulus. The precise sequence of one complete NAP trial is as follows: first, a fixation cross was presented for 1000 ms. After the disappearance of the fixation cross, the prime display consisting of a distractor picture and a target picture was presented on the screen until the participants responded. There were two possible scenarios: either the prime distractor and the prime target shared the same valence (control condition) or the valence
of the prime distractor was different from the prime target (experimental condition). Following the response on the prime display, a blank screen was shown for 1000 ms. Then, another fixation cross was shown and after 1000 ms the probe display started (see Figure 1). Again, two pictures of child faces were presented and the participants were asked to respond to the target picture indicated by a gray or a black frame, while ignoring the distractor. Here, the probe target either had the same valence as the prime distractor (experimental condition) or was different from the prime distractor (control condition). Both the response cue (black or gray frame) and the key assignment were counterbalanced between the participants. Moreover, the sequence of congruent and incongruent prime-probe displays and the spatial position of the target and the distractor were randomly assigned from display to display, with an equal number of presentations for each condition.

Table 1

(Control and experimental condition for negative and positive trials in a NAP task)

<table>
<thead>
<tr>
<th></th>
<th>Negative trials</th>
<th>Positive trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control condition</td>
<td>Experimental condition</td>
</tr>
<tr>
<td>Prime display</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distractor</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Target</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Probe display</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distractor</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Target</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note.* Negative trials measure the effect of negative stimuli; positive trials measure the effect of positive stimuli. Prime displays are used to index interference; the correspondence between prime distractor and probe target is crucial to measure inhibition. + = positive picture; - = negative picture; N = neutral picture.
Figure 1. Example of a complete NAP trial: prime and probe displays (experimental condition). Prime and probe displays include a distractor and a target and are always preceded by a fixation cross.

Procedure

All participants were invited to the lab at the Faculty of Psychology and Educational Sciences. After signing assent/consent, participants were seated in front of a computer and task instructions were displayed on the computer screen. To ensure clarity of the instructions, these were also repeated orally by the experimenter. Before starting with the experiment proper, participants completed 32 practice trials and were able to ask for help if needed. Next, the adolescents were instructed to complete the test phase consisting of 256 trials randomly assigned to 8 blocks of 32 trials (prime + probe display). After finishing the NAP task, all participants filled out the CDI questionnaire. This order of testing prevents priming effects caused by self-report questionnaires and ensures that the CDI questionnaire does not tire or overwhelm participants before starting the NAP task. One of the parents completed the CBCL while waiting for their child to finish the task (Achenbach & Rescorla, 2001; Dutch version by Verhulst et al., 1996).

Only responses that were correct in both prime and probe displays were used for the data analysis. Consistent with previous NAP studies in adults (Goeleven et al., 2006;
Joormann, 2004), extreme reaction times (below 300 ms and above 2000 ms) were considered outliers (anticipated and delayed responses) and were excluded from the analyses. The interference scores were calculated by subtracting the reaction times in the control condition from the reaction times on the experimental condition in the prime displays. Also inhibition scores were computed by subtracting reaction times in the control condition from reaction times in the experimental condition in the probe displays. An interference and inhibition score for positive and negative stimuli was calculated separately for each adolescent.

**Data Analyses**

Given that results of a Shapiro-Wilk test indicated that all NAP indices were not normally distributed (all \( p < .05 \)), a log 10 transformation was used to normalize the distribution of the NAP data. In order to investigate interference and inhibition effects in the two distinct groups, a 2 x 2 x 2 (Priming Condition [control, experimental] x Picture Valence [negative, positive] x Group [dysphoric, non-dysphoric]) repeated-measures ANOVA was conducted. The ANOVA was run twice, once for the interference effect (with response times on the targets of the prime displays as dependent variables) and once for the inhibition effect (with response times on the targets of the probe displays as dependent variables). Furthermore, Pearson correlation coefficients were computed between interference and inhibition scores for positive and negative stimuli to examine the association between inhibition and interference across all participants and separately for each group. Fisher’s r-to-Z transformation was used to compare the correlation coefficients of the dysphoric and the non-dysphoric group.

Because of the continuous development of executive functioning during adolescence (Diamond, 2002), we reran the analyses with age as a covariate of no interest. In addition, since dysphoria and anxiety are frequently associated with one another (AACAP, 2007) and to rule out a potential contributing factor, anxiety was also added as a covariate of no interest. Next, given that the dysphoric group was referred for treatment, there may be other co-occurring symptoms besides anxiety that could influence interference and inhibition processes in this group. Therefore, the overall level of symptoms on the CBCL Total Problems scale was included in the analyses. Further, the impact of gender was explored by also adding this as a covariate of no interest to the repeated measure analyses. Importantly, all abovementioned covariates were entered simultaneously in one model. Finally, to assess the contribution of symptom severity, correlation analyses were performed between CDI scores and the different performance
variables. Effects sizes are provided as partial eta squared ($\eta^2_p$) and Cohen’s $d$, as appropriate. Alpha was set $p = 0.05$, two-tailed. Mean RTs and SDs as a function of group are shown in Table 2.

**Results**

**Group Characteristics**

As expected, groups differed on depressive symptoms, as measured with the CDI, $F(1, 48) = 105.91, p < .001, \eta^2_p = .69$, with a significantly higher score in the dysphoric group (range = 13-35) compared to the non-dysphoric group (range = 1-12). Furthermore, one-way ANOVAs indicated significant group differences on CBCL Anxiety symptoms, $F(1, 48) = 28.03, p < .001, \eta^2_p = .37$, and CBCL Total problem scores, $F(1, 47) = 102.84, p < .001, \eta^2_p = .69$. The CBCL DSM-oriented scales indicated that 76% of the dysphoric adolescents met criteria for affective problems. Noteworthy, 66% of the dysphoric group experienced comorbid affective and other psychological problems, such as anxiety problems (14%), somatic problems (9%), or a combination of these two (14%). In the control group, none of the participants met criteria for psychological problems. The gender distribution did not significantly differ between the two groups, $\chi^2 (1, 49) = 2.31, p = .128$, but a significant difference on age, $F(1, 48) = 7.25, p = .01, \eta^2_p = .13$ emerged (Table 3).

**Interference Effects**

As predicted, the crucial three-way interaction among priming, valence, and group was significant, $F(1, 47) = 16.50, p < .001, \eta^2_p = .26$. Results revealed that the interference score for angry stimuli (with angry distractors and happy targets) was significantly higher in the dysphoric group ($M = 110.19$ ms, $SD = 18.97$ ms) than in the non-dysphoric group ($M = 44.78$ ms, $SD = 78.88$ ms), $t(31) = -4.23, p < .001$, Cohen’s $d = -1.14$ (Figure 2A).

Moreover, results showed that the interference scores for happy stimuli were significantly lower ($M = -41.28$ms, $SD = 49.61$ms) in the dysphoric group compared to the control group ($M = 1.53$ms, $SD = 77.94$), $t(47) = 2.04, p = .047$, Cohen’s $d = -.66$. Specifically, based on one-sample t-tests on the interference scores, there was no interference from happy stimuli (with happy distractors and angry targets) in the control group, $t(27) = -.10, p = .918$, and a facilitation rather than interference from happy stimuli in the dysphoric group, $t(20) = -3.81, p = .001$. 
Table 2
Mean response times and standard deviations (in ms) for the negative affective priming condition as a function of group

<table>
<thead>
<tr>
<th>Prime displays</th>
<th>Dysphoric</th>
<th>Non-dysphoric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>Negative trials</td>
<td>1092 (33)</td>
<td>982 (32)</td>
</tr>
<tr>
<td>Positive trials</td>
<td>962 (28)</td>
<td>1004 (62)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Probe displays</th>
<th>Dysphoric</th>
<th>Non-dysphoric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>Negative trials</td>
<td>1090 (32)</td>
<td>985 (34)</td>
</tr>
<tr>
<td>Positive trials</td>
<td>960 (32)</td>
<td>1003 (63)</td>
</tr>
</tbody>
</table>

Note. Standard deviations are in parentheses.
Table 3

Characteristics of the sample

<table>
<thead>
<tr>
<th></th>
<th>Dysphoric</th>
<th>Non-dypshoric</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n )</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>Depressive symptoms***</td>
<td>18.90 (5.86)</td>
<td>5.57 (3.11)</td>
</tr>
<tr>
<td>Anxiety symptoms ***</td>
<td>4.47 (2.80)</td>
<td>1.25 (1.14)</td>
</tr>
<tr>
<td>Total problem score ***</td>
<td>69.57 (23.58)</td>
<td>18.37 (10.24)</td>
</tr>
<tr>
<td>Age*</td>
<td>13.86 (1.56)</td>
<td>12.78 (1.23)</td>
</tr>
<tr>
<td>Sex (female/male)</td>
<td>17/4</td>
<td>17/11</td>
</tr>
</tbody>
</table>

Note. * \( p < .05 \); *** \( p < .001 \). Standard deviations are in parentheses.

Inhibition Effects

Similar to the interference effects, the same three-way interaction among priming, valence, and group was significant in the inhibition analysis, \( F(1, 47) = 16.64, p < .001, \eta_p^2 = .26. \) Independent \( t \)-tests revealed that the inhibition score for angry stimuli was significantly higher in the dysphoric group \( (M = 104.23, SD = 21.76) \) relative to the control group \( (M = 21.25, SD = 86.77), t(31) = -4.86, p < .001, \) Cohen’s \( d = -1.31 \) (Figure 2B). Moreover, results of independent sample \( t \)-tests indicated no significant differences regarding inhibition of happy stimuli between both groups, \( t(47) = 1.49, p = .143. \)

Relation between Interference and Inhibition

The results of Pearson correlations across all subjects showed a significant positive association between interference scores and inhibition scores for angry stimuli, \( r(47) = .55, p < .001, \) and a marginally significant positive correlation between interference scores and inhibition scores for happy stimuli, \( r(47) = .28, p = .054. \) When differentiating between the two groups, the results indicate a significant positive correlation between interference and inhibition of angry stimuli in both the dysphoric, \( r(19) = .80, p < .001, \) and the non-dysphoric group, \( r(26) = .38, p = .045. \) Furthermore, we found a significant association between interference and inhibition of happy stimuli in the dysphoric group, \( r(19) = .95, p < .001, \) but not in the non-dysphoric group, \( r(26) = -.03, p = .892. \) The results of subgroup analyses revealed that correlations between interference and inhibition are significantly stronger in the dysphoric group compared to the non-dysphoric group, both for angry \( (Z = 2.26, p = .024) \) and happy stimuli \( (Z = 5.83; p < .001). \)
Figure 2. *p < .05; *** p < .001. (A) Mean interference scores (experimental – control; prime displays) and standard error of the mean for positive and negative trials as a function of group. INT pos = interference scores for positive trials; INT neg = interference scores for negative trials. (B) Mean inhibition scores (experimental – control; probe displays) and standard error of the mean for positive and negative trials as a function of group. INH pos = inhibition scores for positive trials; INH neg = inhibition scores for negative trials.
Additional Analyses of Age, Comorbid Anxiety, Gender, Total Problems, and Symptom Severity

All analyses were rerun to examine the impact of age, comorbid anxiety, gender, and total problems on the interference and inhibition effects. Results indicated that the three-way interaction among priming, valence, and group remained significant in the interference analysis, $F(1, 41) = 6.76, p = .01, \eta^2_p = .14$, and in the inhibition analysis, $F(1, 41) = 4.15, p = .048, \eta^2_p = .092$. Moreover, none of the covariates were significant predictors of interference or inhibition (all $p$s > .05). Furthermore, CDI scores were not significantly correlated with the different performance variables (all $p$s > .05, Bonferroni corrected for multiple comparisons).

Discussion

The primary goal of this study was to assess interference and inhibitory processes in dysphoric adolescents by adopting the NAP paradigm. As hypothesized, the results confirmed that dysphoric adolescents experience greater interference from angry facial expressions compared to non-dysphoric adolescents. Furthermore, dysphoric adolescents showed greater inhibition of previously presented angry distractors in comparison to the non-dysphoric group, who did not inhibit distracting angry faces. A noteworthy result is that for both groups positively valenced distractors did not lead to interference and consequently did not have to be inhibited. Moreover, the findings revealed a relationship between interference and the subsequent inhibition of an emotionally valenced stimulus. Apparently, the inhibition effect is dependent on the degree of interference caused by different emotional stimuli in our sample, which is consistent with the results of earlier studies (Goeleven et al., 2010; Gotlib et al., 2005). A closer look to the correlations within the groups revealed that the correlation between interference and inhibition effects was significantly greater in the dysphoric group compared to the non-dysphoric group. The low correlation in the non-dysphoric group can be explained by the small variance in the interference and inhibition scores of angry and happy stimuli.

In general, the results of this study provide empirical support for the presence of an attentional bias for angry faces in dysphoric youngsters. Specifically, dysphoric adolescents demonstrated greater interference compared to non-dysphoric adolescents, as reflected by greater performance impairment by the simultaneous presentation of an angry distractor. This is in line with previous research on depressed and at-risk youngsters for
whom there exist attentional biases for negative information under conditions of long
stimulus exposure (e.g., Hankin et al., 2010; Hommer et al., 2014; Joormann & Gotlib,
2007). Regarding stimulus-specificity, it is worth pointing out that, in contrast to the
majority of previous studies that investigated attentional biases towards sad stimuli (e.g.,
Joormann & Gotlib, 2007; Joormann et al., 2007), the current study used angry faces to
represent negative (social) information. Of interest, in a previous study with angry and sad
stimuli, Hankin et al. (2010) only provided evidence for an attentional bias towards angry
faces in comorbid depressed anxious adolescents, while the pure depressed group only
showed an attentional bias towards sad faces. However, this study differs on two important
aspects with respect to our study. First, the study measured attentional functioning using a
dot probe task. Because this task does not allow the distinguishing between different
attentional processes, results cannot be directly compared with the present study. Second,
while Hankin et al. (2010) included adolescents diagnosed with a major depressive
disorder, the current study focused on dysphoric adolescents who are referred for
emotional problems for the first time, prior to any diagnosis and who are also medically
naive.

With regard to the effect of positive stimuli, results indicated that interference from
happy distractor faces was significantly lower in the dysphoric group compared to the non-
dysphoric group. More concretely, relative to controls, dysphoric youngsters were
significantly faster in prime displays with a happy distractor (experimental condition;
different valence as the target) relative to prime displays with an angry distractor (control
condition, same valence as the target). This suggests that happy faces facilitate their
response to the target stimulus. A potential explanation for this result is that dysphoric
adolescents have the tendency to direct their attention away from positive social
information (schema-incongruent) and therefore show a faster response time to the target
stimulus in the presence of a happy distractor (Leppanen, 2006). This is in contrast to angry
distractors (schema-congruent), which capture their attention and reduce the capacity to
selectively attend to the relevant target picture. Moreover, these results provide additional
evidence for differences in processing happy versus angry stimuli in dysphoric adolescents
(Gotlib, Kasch, et al., 2004; Gotlib, McLachlan, & Katz, 1988).

On the level of inhibitory processes, a pronounced inhibition of angry stimuli was
observed in dysphoric individuals compared to non-dysphoric ones. That is, dysphoric
participants responded slower to angry probe targets if the previous prime distractor had
the same valence. These findings indicate that dysphoric adolescents were more easily
distracted by angry faces and subsequently inhibit them more. This corresponds to the results of previous studies indicating a higher inhibition of angry faces (Zetsche & Joormann, 2011) and negatively valenced words (Gotlib et al., 2005) in students suffering from depressive symptoms.

However, the current findings are inconsistent with those found in several similar NAP studies, which indicated less inhibition of negative stimuli in depressed adults (Goeleven et al., 2006; Joormann, 2004). First, the discrepancy may be associated with stimulus-specific differences. For instance, despite using the same pictorial task design, previous studies included sad faces, while the current study relied on angry faces as negative emotional information. Since angry faces might activate depression-related schemas of social rejection and therewith increase negative affect, these stimuli might be highly interfering and evoke strong inhibitory responses (Gilboa-Schechtman et al., 2004; Hames et al., 2013). This contrasts with sad faces, which are congruent with a depressed mood state and therefore are considered to be less salient or distracting to dysphoric individuals. This is consistent with the NAP study of Zetsche and Joormann (2011), which included both sad and angry faces and showed a lower inhibition of sad stimuli and a higher inhibition of angry stimuli in students with depressive symptoms. Furthermore, when considering NAP studies investigating inhibitory processes using verbal stimuli, evidence is found for both a higher and a lower inhibition of negative stimuli (Gotlib et al., 2005; Joormann, 2004). Because negative verbal stimuli might be associated with a broad range of negative emotions (e.g., sadness, fear, disgust, anger, …), it is not clear to which extent the nature of inhibitory dysfunction is stimulus specific in these findings.

Second, the different results may also be explained by developmental differences between adolescent and adult samples. Although previous studies have shown a lower inhibition of negative stimuli in depressed adults (e.g., Goeleven et al., 2006; Joormann & D'Avanzato, 2010), this study indicates a higher inhibition of angry faces in dysphoric adolescents. This might point to a higher cognitive investment to deal with the attentional disturbance from angry stimuli in dysphoric youngsters compared to depressed adults. This is in line with past research findings, which suggest a negative association between longitudinal depression severity and executive functioning in adults (Harvey et al., 2004). However, caution is warranted in drawing conclusions since this study differs from other NAP studies both in terms of developmental level and stimulus characteristics. Moreover, including age as a covariate in our analyses did not change the reported results. It is clear
that more research in medication-free adolescents using mental health services for the first time is needed to fully understand the differences with previous studies.

Our findings are further inconsistent with a recent meta-analysis of cognitive functions in depressed children and adolescents, which reported consistent deficits in inhibitory capacity (Wagner, Muller, Helmreich, Huss, & Tadic, 2015). However, the meta-analysis of Wagner et al. (2015) relied on non-emotional Stroop tasks for investigating inhibitory functioning in depressed youth. Therefore, the explanation for the incongruence may lie in the different nature of the tasks involved. Specifically, in contrast to the NAP task, the Stroop task does not allow to present more than one stimulus at a time, which makes it impossible to map different aspects of attention (Koster, Crombez, Verschuere, & De Houwer, 2004). Consequently, findings from Stroop and NAP tasks might be influenced by different underlying processes, making it impossible to compare them with one another. In addition, while the current study has focused on emotional interference on cognitive functioning, the meta-analysis of Wagner et al. (2015) included studies using neutral stimuli and thus only provided evidence for a general cognitive impairment in depressed youth.

From a clinical viewpoint, we assume that malfunctioning attentional processing of angry stimuli might be related to emotion regulation difficulties. Specifically, dysphoric adolescents showed a heightened interference of angry distractors during cognitive processing, indicating problems with the bottom-up filtering of emotional information. Consequently, the increased negative affect and the emotional lability that characterizes dysphoric adolescents may be related to problems in this attentional process. Moreover, we hypothesize that the heightened interference and subsequent inhibition of negative (social) information draw largely on cognitive resources and reduce cognitive capacity, thereby leading to difficulties regulating negative emotions. In this context, an interesting avenue for future research is to investigate further the impact of different attentional processes on emotions in early adolescent samples and to explore how these negative attentional biases would shift after participating in an emotion regulation training. On this topic, promising results in depressed adults have already been discussed in the review by Joormann and Vanderlind (2014). Moreover, identifying the precise early underlying cognitive processes in dysphoric adolescents is highly important as it may also stimulate the development of age-appropriate preventive treatment strategies that reduce the impact of subclinical depressive symptoms before a chronic course emerges (Pine et al., 1999).
The main strength of the study lies in its focus on several aspects of attentional functioning in a sample consisting of dysphoric adolescents. Because adolescence proves a critical period of vulnerability to depression and given the elevated risk of a depressive disorder in adulthood following first-onset depression in adolescence (Fombonne, Wostear, Cooper, Harrington, & Rutter, 2001), research on the underlying mechanisms in this age group is undoubtedly needed.

Moreover, although previous studies in depressed adults are limited by depression severity and recurrent episodes, studying dysphoric adolescents who are referred for the first time, enables us to have a clearer look at the baseline cognitive processes. Furthermore, in contrast to many other studies of attentional biases using emotional words as stimuli (e.g., Joormann, 2004; Joormann & D'Avanzato, 2010), the NAP task adopted in this study included pictures of child faces to provide higher ecological validity. We specifically focused on angry faces, as these stimuli are presumed to represent relevant social stimuli for the participants, given the profound interpersonal difficulties and social rejection depressed individuals experience (Hames et al., 2013). Additionally, the use of a pictorial NAP task, consisting of prime and probe displays, enabled us to explore attentional functioning in great depth because the subprocesses of stimulus selection and subsequent inhibition could be differentiated.

However, in interpreting the results of this study, several limitations should be acknowledged. First, we assessed depressive symptoms through a self-report questionnaire (CDI; Kovacs, 1992; Dutch version by Timbremont & Braet, 2002). Although the CDI is a reliable depression screening instrument, the use of a structured clinical interview is required to diagnose the presence of a major depressive disorder (Hien et al., 1998). Even though all the clinical participants in our study were referred for emotional problems, replication of these results is needed with a sample of diagnosed depressed adolescents.

Another limitation is that we used parent-reports of child anxiety. Since adolescents are a better reporter of their internalizing problems compared to their parents (Achenbach, Mcconaughy, & Howell, 1987), the effects of anxiety might have been lessened as a result of the source of information. However, the results of a study conducted by Bodden, Bogels, and Muris (2009), who investigated the diagnostic utility of a specific screening tool for identifying anxiety disorders in youngsters (8-18 years old), indicated that parent report of anxiety had highest sensitivity and specificity compared to self-report and could be seen as the most reliable way to screen for anxiety problems in children and
adolescents. Moreover, including anxiety symptoms in the analyses as a covariate of no interest did not alter the main findings.

In contrast to most previous studies that focused on sad stimuli (e.g., Goeleven et al., 2006; Joormann et al., 2007), the current study examined depression-related processing biases in relation to angry facial expressions. Since sad faces were not included in our stimulus set, we could not compare the effects of different types of negative stimuli on interference and inhibition processes. Therefore, the present results do not allow us to determine whether the observed effects are stimulus-specific or relate to negative emotional stimuli in general.

Finally, it will be interesting to replicate this study on adolescents at the risk of depression and previously depressed adolescents in order to explore if attentional biases play a role in the development or recurrence of depression and not merely represent a symptom of depressed mood. In fact, if future research continues to demonstrate the important role of maladaptive attentional processes in the etiology and maintenance of depression in youngsters, current prevention programs will have to take account of specific cognitive risk factors and make improvements accordingly (Siegle, Ghinassi, & Thase, 2007).

**Conclusions**

The results of the current study provide new insights regarding attentional processing in dysphoric adolescents. Specifically, the findings show that dysphoric adolescents show higher interference from and higher inhibition of angry faces relative to non-dysphoric adolescents. Importantly, this finding contrasts with previous NAP studies in depressed and dysphoric adults indicating less inhibition of sad faces or negatively valenced words. Therefore, we may assume that depression-related inhibitory processes are stimulus specific. Although angry faces activate schemas of social rejection and therefore evoke a strong inhibitory response, sad faces are mood-congruent and are considered to be less threatening for depressed or dysphoric individuals. Furthermore, the inconsistency with previous research might also reflect developmental differences between adolescent and adults samples in depressogenic information processing. However, since our study differs with other NAP studies both in terms of developmental level and stimulus characteristics, more research is needed to clearly understand the observed differences. It will be important for future studies to more closely investigate the impact of both sad and angry stimuli on different components of attentional functioning in
depressed and dysphoric individuals. Moreover, longitudinal studies are needed to assess interference and inhibition processes in at risk-youngsters and adolescents diagnosed with depression to explore the role of attentional processes in the development and maintenance of depression.
Acknowledgments

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INTERNAL SHIFTING IMPAIRMENTS IN RESPONSE TO EMOTIONAL INFORMATION IN DYSPHORIC ADOLESCENTS

Abstract

Previous studies have suggested that internal cognitive control impairments may play an important role in the development of depression. Despite a growing body of research in adults, the ability to shift internal attention between mental representations in working memory has received little attention in younger populations. This study investigated internal shifting capacity between emotional and non-emotional information in dysphoric and non-dysphoric adolescents. Twenty dysphoric and 34 non-dysphoric adolescents (10-17 years) completed an Internal Shifting Task, with pictures of angry and neutral faces, to measure the ability to shift attention between information held in working memory. Dysphoric adolescents showed specific shifting impairments when processing emotional material relative to non-dysphoric adolescents. Valence-specific analyses revealed that shifting was particularly impaired when shifting from negative to neutral information. By comparison, relative to non-dysphoric adolescents, dysphoric adolescents did not show shifting impairments when non-emotional features of the pictures had to be processed. The study is limited by the absence of a structured clinical interview as dysphoria was determined dimensionally. Furthermore, a comparison of the effects of different negative stimuli on shifting could not be made since sad stimuli were not included.

in the stimulus set. The results confirm the link between depressive symptoms and emotion-specific shifting impairments in adolescents and indicate that targeting shifting ability in response to emotional stimuli may be a promising avenue for prevention programs. Longitudinal research is needed to replicate results and to explore the role of internal shifting impairments in the etiology and maintenance of depression.
Introduction

Depressive symptoms in adolescents are common (Balazs, 2013) and have a variety of negative consequences, such as impaired social relationships and an increased risk for suicide (Birmaher et al., 1996; Horowitz & Garber, 2006). Moreover, adolescent depressive symptoms are highly predictive for chronic and severe depressive episodes in adulthood (Lewinsohn, Rohde, Seeley, Klein, & Gotlib, 2000), which indicates the need to study underlying cognitive processes in dysphoric adolescents before a chronic course emerges.

Cognitive theories have mainly focused on the content of depressive cognition and assigned a crucial role to negative schemas of the self, world, and future in the development and persistence of depression (Beck, 1976). The proposition that cognitive schemas have a major influence on the processing of information stimulated research on the relationship between cognitive processes and depressive symptoms. Results of these studies provided evidence for depression-related information processing biases (Neshat-Doost, Taghavi, Moradi, Yule, & Dalgleish, 1998; Timbremont, Braet, Bosmans, & Van Vlierberghe, 2008) and indicated a better memory for negative information and an attentional bias towards negative information among adolescents who are currently depressed or at risk for depression (Gibb, Benas, Grassia, & McGeary, 2009; Hankin, Gibb, Abela, & Flory, 2010). It is assumed that these negative processing biases lead to repetitive negative thoughts (i.e. rumination) and sustained negative affect, which in turn contribute to and intensify depressive symptoms (Clark & Beck, 2010). Despite the interesting findings regarding depressogenic information processing, so far it is still unclear to what extent adolescent depressive symptoms are associated with impairments on the level of fundamental cognitive control processes, which refer to executive functions such as working memory. Yet, the investigation of such processes is of particular interest since it has been shown that the capacity to cognitively control incoming information positively impacts one’s ability to deal with stressful events and to manage emotional responses (Ochsner & Gross, 2005).

Depressive Symptoms and Cognitive Control Impairments

Cognitive control refers to the ability to selectively attend to relevant stimuli, select and maintain relevant goals, and inhibit the processing or response to irrelevant or previously relevant stimuli (Brydges, Anderson, Reid, & Fox, 2013; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). This ability is related to three important
executive functions: shifting between tasks or mental sets (shifting), inhibiting dominant responses or irrelevant information (inhibition), and monitoring and updating the contents of working memory (updating) (Miyake et al., 2000). Recently, it has been proposed that impaired cognitive control may be an important component for understanding prolonged negative affect and recurrent negative thoughts in depression (Joormann & D'Avanzato, 2010; Koster, De Lissnyder, Derakshan, & De Raedt, 2011). The majority of the past studies on cognitive control in depressed or dysphoric adolescents have used cognitive control tasks including non-emotional information and provided mixed results with only a few studies indicating a clear group difference (for a review see Vilgis, Silk, & Vance, 2015). The little research that demonstrated group differences regarding cognitive control ability showed that depressed adolescents were less accurate (i.e., higher error rates) and responded more slowly (i.e., higher response times) compared to healthy adolescents (Bloch et al., 2013; Gunther, Konrad, De Brito, Herpertz-Dahlmann, & Vloet, 2011; Hardin, Schroth, Pine, & Ernst, 2007). However, multiple studies on cognitive control functions yielded mixed or no results (Han et al., 2012; Kyte, Goodyer, & Sahakian, 2005; Wilkinson & Goodyer, 2006). For instance, previous studies investigating general shifting, determined by tests such as the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948), were inconclusive showing either no difference between depressed adolescents and healthy controls (Favre et al., 2009) or a lower score on shifting in the depressed group (Gunther et al., 2011; Holler, Kavanaugh, & Cook, 2014). By contrast, studies examining inhibition, with an antisaccadic eye movement task (Hardin et al., 2007) or a go/no-go task (Gunther et al., 2011) provided some support for impaired inhibition in depressed or dysphoric adolescents, yet, empirical evidence is far from being consistent (Vilgis et al., 2015).

Given prior inconclusive results regarding general cognitive control impairments, one possibility is that cognitive control in dysphoric or depressed adolescents might be particularly disturbed when processing emotional information (Joormann, Yoon, & Zetsche, 2007; Koster et al., 2011; Vilgis et al., 2015). Although research using cognitive control tasks including emotional stimuli in pediatric mood disorders and dysphoric adolescents is rather scarce (for a review see Mueller, 2011), a few studies have provided such evidence. Ladouceur et al. (2005) and Tavitian et al. (2014) administered an Emotion N-back task and found evidence for working memory impairments in the presence of emotional and neutral information in depressed youngsters compared to healthy controls. Furthermore, results from the affective go/no go task also support impaired processing of
negative stimuli in adolescents suffering from depression (Kyte et al., 2005; Ladouceur et al., 2006; Maalouf et al., 2012). Finally, a study using the Negative Affective Priming task showed a higher interference and inhibition of negative stimuli in dysphoric adolescents compared to healthy controls (Wante, Mueller, Demeyer, De Raedt, & Braet, 2015). Although the aforementioned studies provide initial evidence for dysfunctional cognitive control over emotional stimuli, it has recently been proposed that depressed people might experience specific difficulties with internal cognitive control rather than with external cognitive control processes (Koster, De Lissnyder, & De Raedt, 2013).

**Depressive Symptoms and Internal Shifting Ability**

Whereas external cognitive control refers to the selection and modulation of external information, such as perceptual attributes of cues or targets, internal cognitive control can be described as the ability to process and modulate internally generated information, such as mental sets in working memory (Chun, Golomb, & Turk-Browne, 2011; Wager, Jonides, & Smith, 2006). Impaired internal control over negative thoughts may result in difficulties regulating negative affect and thus might be of particular relevance in the development of depressive symptoms (Koster et al., 2013). An interesting paradigm to explore shifting between mental representations in working memory is the Internal Shifting Task (IST; Chambers, Lo, & Allen, 2008; De Lissnyder, Koster, & De Raedt, 2012), which is an affective variant of the shifting task of Garavan (1998) and Gehring, Bryck, Jonides, Albin, and Badre (2003). The IST used in this study includes pictures of faces and consists of an emotional and a non-emotional condition. In the emotional condition, participants are asked to perform a silent mental count of the number of negative and neutral faces. In the non-emotional condition, participants are instructed to mentally count the amount of male and female faces. The IST design allows to measure efficiency of general shifting (across emotional and non-emotional condition), condition-specific shifting (emotional condition vs. non-emotional condition), and valence-specific shifting (shifting from negative to neutral or vice versa). Results of a study in depressed adolescents and young adults using an IST with neutral and affective words revealed greater shifting difficulties in the emotional condition compared to healthy controls (Lo & Allen, 2011). Moreover results of prospective studies in adults using a pictorial IST indicated that emotion-specific shifting impairments are associated with increased rumination in response to stress (De Lissnyder, Koster, Goubert, et al., 2012) and play an important role in the prediction of depressive symptoms at one year follow up (Demeyer, De Lissnyder, Koster, & De Raedt, 2012).
The Current Study

Despite the increased risk for an adult depressive episode in adolescents with depressive symptoms (Pine, Cohen, Cohen, & Brook, 1999), research on the role of internal cognitive control in response to emotional stimuli in dysphoric adolescents remains scarce. The present study aimed to examine internal shifting ability in dysphoric adolescents with the use of the IST including pictures of angry and neutral faces (De Lissnyder, Koster, & De Raedt, 2012). In line with prior shifting studies in adults (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; De Lissnyder, Koster, Everaert, et al., 2012; De Lissnyder, Koster, Goubert, et al., 2012; Demeyer et al., 2012; Koster et al., 2013), we included angry faces as negative target stimuli in that these kind of emotional stimuli are thought of bearing direct personal relevance to adolescents suffering from depressive symptoms and can be associated with depression-related interpersonal difficulties and schemas of social rejection (Gotlib, Krasnoperova, Yue, & Joormann, 2004; Hames, Hagan, & Joine, 2013; Mueller, De Rubeis, Lange, Pawelzik, & Sutterlin, 2016). According to interpersonal theories of depression, depressed individuals engage in inappropriate social behaviors that are likely to elicit social rejection, which in turn confirms negative schemas and increases depressive symptoms (Coyne, 1976; Joiner, Alfano, & Metalsky, 1992). Since angry faces might activate depression-related schemas of social rejection and therewith increase negative affect, these stimuli may strongly attract attention in dysphoric adolescents (Gilboa-Schechtman, Ben-Artzi, Jeczemien, Marom, & Hermesh, 2004).

The study had three specific goals. First, we investigated whether dysphoric adolescents relative to unaffected adolescents showed general shifting impairments. Based on prior research in depressed or dysphoric adolescents which failed to find general cognitive control deficits (Vilgis et al., 2015), and shifting deficits in particular (Favre et al., 2009), we expected no differences between the groups with regard to general shifting impairments. Second, we aimed to investigate to what extent dysphoric adolescents showed specific shifting impairments when processing the emotional features of the target stimuli. Drawing on a few studies investigating cognitive control of emotional stimuli in adolescents with elevated depressive symptoms (Maalouf et al., 2012; Tavitian et al., 2014; Wante et al., 2015) and prior internal shifting studies among currently depressed and at-risk individuals (De Lissnyder, Koster, Goubert, et al., 2012; Demeyer et al., 2012; Koster et al., 2013; Lo & Allen, 2011), we hypothesized a greater shift cost in the emotional condition compared to the non-emotional condition only in the dysphoric group. Finally,
we explored whether dysphoric adolescents showed *valence-specific* shifting impairments. On the basis of recent cognitive models of depression (Joormann & D'Avanzato, 2010; Koster et al., 2011), we predicted higher shift costs related to shifting from angry to neutral information compared to shifting from neutral to angry information in dysphoric adolescents but not in non-dysphoric adolescents.

Because of the continuous development of cognitive control processes, such as shifting between mental sets, during adolescence (Diamond, 2002) and gender differences in the neural processes of cognitive control (Koch et al., 2007; Li et al., 2009), age and gender were included as standard covariates throughout all analyses. Moreover, to filter out the confounding effects of other relevant variables that may impact differences shifting ability between the dysphoric and the non-dysphoric group, we explored the impact of several covariates of no interest in a second round of analyses. Based on previous adult studies indicating an association between rumination and shifting (De Lissnyder et al., 2010; De Lissnyder, Koster, Goubert, et al., 2012; Demeyer et al., 2012; Koster et al., 2013), we added rumination as a control variable to exclude its potential contribution to the results. Furthermore, since dysphoria and anxiety are frequently associated with one another (AACAP, 2007) and to rule out a potential contributing factor, we added anxiety symptoms as a control variable. Next, we controlled for other co-occurring symptoms besides anxiety that could influence shifting ability in the dysphoric group by including the overall level of psychopathology symptoms. Finally, given that working memory and intelligence appear to be highly correlated (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014), we also controlled for intelligence.

**Materials and Methods**

**Participants**

Eighty-two adolescents between 10 and 17 years of age (54% female, mean age = 12.30, \( SD = 1.65 \)) volunteered for this study. In order to obtain a youth sample with a broad range of depressive symptoms, non-referred \( n = 41 \) or 50\%), at-risk \( n = 24 \) or 29\%), and referred adolescents \( n = 17 \) or 21\%) were included in the sample. Non-referred adolescents were recruited through advertising in schools. At-risk youngsters were selected from a screening sample of youngsters who were participating in a larger, school-based study. Youngsters from the screening sample were invited to the study if their scores were above or equal to a cut-off score of 11 on the Children’s Depression Inventory (CDI; Kovacs, 1992; Mattison, Handford, Kales, & Goodman, 1990). A cut-off score of 11 on
the CDI has been shown to have relatively good psychometric properties in predicting depression in youth and is considered to represent mild levels of depression (Kaslow, Rehm, & Siegel, 1984; Shemesh et al., 2005; Worchel et al., 1990). The referred adolescents were recruited from two clinical centers and were invited if they were referred for treatment of internalizing problems. Twenty-eight participants were excluded from the analyses due to accuracy rates below 60% on the IST. These participants did not significantly differ from the final sample on the basis of gender, age, intelligence, or depressive symptoms (all $p > .085$). This resulted in a final sample of 54 adolescents (57% female, mean age $= 12.30$, $SD = 1.19$; see Table 1). Based on their CDI scores at the moment of testing, participants were classified as dysphoric (CDI $\geq 11$; $n = 20$) or non-dysphoric (CDI $< 11$; $n = 34$). In the dysphoric group (range CDI scores $= 11-25$), 25% were from the referred sample, 45% from the at-risk sample, and 30% from the non-referred sample, whereas in the non-dysphoric group (range CDI scores $= 0-10$), 67% were from the non-referred sample, 15% from the at-risk sample, and 18% from the referred sample. Age and gender of the participants were included as standard covariates in all analyses. The research protocol was approved by the Ethics Committee of Ghent University Hospital. Youngsters signed informed assent while legal guardians signed informed consent. After completing the questionnaires and the task, participants were compensated with two cinema tickets.

**Measures**

**Depressive symptoms.** The CDI (Kovacs, 1992; Dutch version by Timbremont & Braet, 2002) is a 27-item self-report questionnaire designed to assess depressive symptoms in youth. Each item has three response options, which vary in severity (e.g., “I do most things wrong”, “I do many things wrong”, “I do everything wrong”). The CDI showed good psychometric qualities in terms of internal consistency and test-retest reliability in non-clinical samples (Craighead, Smucker, Craighead, & Ilardi, 1998; Timbremont & Braet, 2002). Cronbach’s alpha on the CDI in this sample was $\alpha = .80$.

**Rumination.** The FEEL-KJ is a 90-item self-report measure and is designed to assess adaptive and maladaptive emotion regulation (ER) strategies in response to anxiety, sadness, and anger (Cracco, Van Durme, & Braet, 2015). The items are rated on a five-point scale, ranging from never to almost always. The FEEL-KJ has been shown to have good psychometric qualities, in terms of reliability and validity (Cracco et al., 2015; Grob & Smolenski, 2005). In the current study, only the subscale “Rumination” was used and Cronbach’s alpha was .69.
INTERNAL SHIFTING IMPAIRMENTS IN DYSPHORIC ADOLESCENTS

Table 1
Characteristics of the sample

<table>
<thead>
<tr>
<th></th>
<th>Dysphoric</th>
<th>Non-dypshoric</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>Depressive symptoms***</td>
<td>15.80 (4.50)</td>
<td>6.82 (2.81)</td>
</tr>
<tr>
<td>Rumination</td>
<td>18.92 (4.71)</td>
<td>16.78 (4.83)</td>
</tr>
<tr>
<td>Anxiety symptoms ***</td>
<td>40.85 (5.45)</td>
<td>33.60 (6.64)</td>
</tr>
<tr>
<td>Total problem score *</td>
<td>41.00 (26.20)</td>
<td>26.52 (20.41)</td>
</tr>
<tr>
<td>Age **</td>
<td>13.10 (1.92)</td>
<td>11.82 (1.55)</td>
</tr>
<tr>
<td>Intelligence</td>
<td>43.15 (6.78)</td>
<td>41.64 (6.33)</td>
</tr>
<tr>
<td>Sex (female/male)</td>
<td>14/6</td>
<td>17/17</td>
</tr>
</tbody>
</table>

Note. *p < .05; **p ≤ .01; *** p < .001. Standard deviations are in parentheses.

**Trait Anxiety.** The trait version of the State-Trait Anxiety Inventory for Children (STAI-TC; Bakker, Wieringen, Ploeg, & Spielberger, 2004; Spielberger, 1973) is a 20-item self-report questionnaire that assesses the frequency and intensity of anxiety symptoms. Items are rated on a 3-point Likert scale with 1 = ‘almost never’ and ‘3’ = often. The STAI-TC is considered as a reliable and valid measure for assessing anxiety symptoms in youngsters. Internal consistency in this study was good with a Cronbach’s alpha of .86.

**General Psychopathology.** The Child Behavior Checklist is a parent-report questionnaire measuring emotional and behavioral problems in youngsters (CBCL; Achenbach & Rescorla, 2001; Dutch version by Verhulst, Ende, & Koot, 1996). It consists of 113 items, which are scored on a three-point scale. In this study, only the CBCL Total Problem scale was used and Cronbach’s alpha was good with α = .95.

**Intelligence.** Raven’s Standard Progressive Matrices (SPM) is a non-verbal IQ measure that consists of 60 incomplete matrices (Raven, Court, & Raven, 1977). For each matrix, the participant is presented with 6 pieces and is instructed to choose the one that best fits the missing part. Results of psychometric studies indicate that SPM is a good predictor of fluid intelligence and correlates strongly with general intelligence (Spearman’s g; e.g., Carroll, 1993; Flanagan & McGrew, 1998; Rushton, 1998).
**Internal Shifting Task.** The IST (De Lissnyder, Koster, & De Raedt, 2012) was programmed using the E-prime 2.0 software package and was run on a laptop with a 72-Hz, 17-inch color monitor. The pictorial stimuli were selected from two validated databases: a recently developed database of child face images (Verfaillie, Theuwis, & Wante, 2012) and the child faces of the Radboud Faces Database (Langner et al., 2010). The pictures were set at 360 x 360 pixels and were adjusted to reduce interference of background stimuli (hair). The final stimulus set included 24 neutral faces and 24 angry faces. Participants were told that pictures of faces would appear in the center of the screen one at a time. They were asked to silently count the amount of pictures in a certain category observed over the block of trials. There were two task conditions: an emotional condition and a non-emotional condition. In the emotional condition (or emotion condition), participants had to focus on the emotion of the pictures and were asked to perform a silent mental count of the number of angry and neutral faces. In the non-emotional condition (or gender condition) participants had to focus on the gender of the pictures and were asked to mentally count of the number of male and female faces. When a stimulus was presented, the subjects had to press the spacebar as quickly as possible to indicate that they had internally updated the counters of the categories and this allowed to measure reaction time. The next picture was shown 200 ms after pressing the spacebar. At the end of each block, participants were instructed to report the number of pictures in each category and this was used to measure accuracy. The emotional and non-emotional condition were performed sequentially and the order in which the conditions were completed was counterbalanced across participants. Both conditions consisted of 12 blocks of trials with at random 10 to 14 presented pictures within each block. Each block of trials consisted of shift and repeat trials. A shift trial refers to a trial in which the target picture has to be updated on a different category as the preceding picture (n-1). A repeat trial refers to a trial in which the target stimulus has to be updated on the same category as the preceding picture (n-1). An example of a block of items, including shift and repeat trials, and a stimulus display is shown in Figure 1.
Figure 1. Example of a block of items and a stimulus display. In the emotional condition (shown in the left half of the figure), participants have to focus on the emotion of the pictures and are asked to perform a mental count of the number of angry and neutral faces. In the non-emotional condition (shown in the right half of the figure), participants have to focus on the gender of the pictures and were asked to keep a silent mental count of the number of male and female faces. In shift trials, the target picture has to be updated on a different category as the preceding picture. In repeat trials, the target stimulus has to be updated on the same category as the preceding picture.

Procedure

All participants were invited to the lab at the Faculty of Psychology and Educational Sciences. After signing assent/consent, participants were seated in front of a computer and received task instructions both orally and in writing. Before starting with the
experiment proper, participants completed the practice phase including three blocks of items. Next, the adolescents were instructed to complete the experiment phase consisting of 12 blocks of items in both the emotional and the non-emotional condition. After finishing the IST, all participants completed Raven’s SPM and filled out the self-report questionnaires. This order of testing prevents priming effects caused by self-report questionnaires and ensures that the intelligence test or questionnaires do not tire or overwhelm participants before starting the IST. One of the parents completed the CBCL while waiting for their child to finish the task.

**Data Analyses**

In order to analyze shifting impairments in the two groups, a $2 \times 2 \times 2$ (Condition [emotion, gender] x Shift Type [shift, repeat] x Group [dysphoric, non-dysphoric]) repeated-measures (rm)ANCOVA was conducted on response time (RT) data. To further investigate significant interactions, shift costs were calculated by subtracting RTs in repeat trials from RTs on shift trials. Several types of shift costs are examined: (1) to explore general impairments in shifting ability, shift costs across the emotional and the non-emotional condition are examined (*general shift cost*); (2) to explore shifting impairments related to the task relevance of emotional information, shift costs within the emotional condition (*emotion shift cost*: RT shift trials (angry-neutral, neutral-angry) minus RT repeat trials (angry-angry, neutral-neutral)) and the non-emotional condition (*gender shift cost*: RT shift trials (male-female, female-male) minus RT repeat trials (male-male, female-female)) are assessed; and (3) to explore shift and repeat trials within the emotional condition, shift and repeat sequences within the emotional condition are compared, referred to as valence face N-1 followed by valence face N (angry-neutral, neutral-angry; angry-angry, neutral-neutral). The effort required to engage attention towards angry faces, is calculated by subtracting reaction times in neutral-neutral trials from reaction times in neutral-angry trials (*engagement cost*). The effort required to disengage attention from angry faces towards neutral faces, is calculated by subtracting reaction times in angry-angry trials from reaction times in angry-neutral trials (*disengagement cost*).

To ensure that no other relevant variables were related to the differences in shifting ability between the dysphoric and non-dysphoric group, we reran all analyses and added rumination, anxiety symptoms, overall level of psychopathology symptoms (CBCL Total Problems), and intelligence (total score on Raven’s SPM) as covariates of no interest. Since all effects remained significant after adding all abovementioned covariates simultaneously to the model, the results of this additional analysis are not further
discussed. Effects sizes are provided as eta squared ($\eta^2$) and Cohen’s $d$, as appropriate. Alpha was set at $p = 0.05$, two-tailed. Analogous to previous IST studies (e.g., De Lissnyder, Koster, Everaert, et al., 2012; Demeyer et al., 2012), median RT were used in the RT analyses to reduce the influence of outliers on the data. Overall means and SDs as a function of group are shown in Table 2. The average accuracy rate was 75%, with a significant difference between conditions, $F(1, 52) = 58.41, p < .001, \eta^2 = .52$. Consistent with earlier research in adults (Koster et al., 2013), accuracy rates were higher in the emotional condition ($M = 86\%, SD = 11\%$) compared to the non-emotional condition ($M = 64\%, SD = 17\%$). There was no significant difference in accuracy rate between both groups, $F(1, 52) = 1.42, p = .24, \eta^2 = .01$.

**Results**

**Group Characteristics**

As expected, groups differed on depressive symptoms, $F(1, 52) = 81.66, p < .001, \eta^2 = .61$, with a significantly higher score in the dysphoric group compared to the non-dysphoric group. The mean score on rumination did not significantly differ between both groups, $F(1, 51) = 2.31, p = .135, \eta^2 = .04$. One-way ANOVAs indicated significant group differences on anxiety symptoms, $F(1, 51) = 16.92, p < .001, \eta^2 = .25$, total problem scores, $F(1, 47) = 4.72, p = .035, \eta^2 = .09$, and age, $F(1, 52) = 7.17, p = .01, \eta^2 = .12$. No significant differences between the two groups were found for intelligence $F(1, 51) = .67, p = .41, \eta^2 = .01$, or gender distribution, $\chi^2 (1, 54) = 2.06, p = .151$ (Table 1).

**Shifting Impairments in Emotional and Non-emotional Condition**

The results of the rmANCOVA with Condition (emotion, gender) and Shift Type (shift, repeat) as within-subject factors and Group (dysphoric, non-dysphoric) as between-subject factor indicated a significant main effect of Condition, $F(1, 49) = 5.26, p = .026, \eta^2 = .05$, with slower response times to the emotion condition ($M = 1793 \text{ ms}, SD = 488 \text{ ms}$) than to the gender condition ($M = 1620 \text{ ms}, SD = 340 \text{ ms}$). Analyses also revealed a significant main effect of Shift Type, $F(1, 49) = 14.22, p < .001, \eta^2 = .07$, with slower response times to shift trials ($M = 1963 \text{ ms}, SD = 403 \text{ ms}$) than to repeat trials ($M = 1366 \text{ ms}, SD = 346 \text{ ms}$). Most importantly, analyses showed a significant three-way interaction among Condition, Shift Type, and Group, $F(1, 49) = 10.66, p = .002, \eta^2 = .03^2$. To further explore these results, we examined general and condition-specific shift costs. There were

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2 The three-way interaction is also significant when excluding referred adolescents with low CDI scores from the non-dysphoric group, $F(1, 43) = 9.88, p = .003, \eta^2 = .03$. 

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no significant differences between the groups with regard to general shift cost, \( t(52) = .07, p = .946, \) Cohen’s \( d = .02 \). Results of between-group analyses showed that the shift cost in the emotion condition was significantly higher in the dysphoric group compared to the non-dysphoric group, \( t(52) = -2.46, p = .017, \) Cohen’s \( d = .65 \), while there was a trend significant group difference on shift costs in the gender condition, \( t(51) = 1.95, p = .056, \) Cohen’s \( d = .50 \). Moreover, results of within-group comparisons revealed that, for the dysphoric group, the shift cost in the emotion condition was significantly higher than in the gender condition, \( t(19) = 2.55, p = .02, \) Cohen’s \( d = .78 \). For the non-dysphoric group, however, the shift cost in the gender condition was significantly higher than the shift cost in the emotion condition, \( t(33) = -2.13, p = .04, \) Cohen’s \( d = .38 \) (Figure 2A).

**Valence-specific Shifting Impairments**

The results of the rmANCOVA with Valence Face \( N-1 \) (neutral, angry) and Valence Face \( N \) (neutral, angry) as within-subject factors and Group (dysphoric, non-dysphoric) revealed a significant interaction between Valence Face \( N \) and Group, \( F(1, 49) = 6.28, p = .016, \) \( \eta^2 = .04 \), and between Valence Face \( N-1 \) and Valence Face \( N \), \( F(1, 49) = 6.89, p = .012, \) \( \eta^2 = .06 \). Most importantly, a significant three-way interaction was obtained between Valence Face \( N-1 \), Valence Face \( N \), and Group, \( F(1, 49) = 4.64, p = .036, \) \( \eta^2 = .04 \). Results of between-group analyses showed no significant differences between groups with regard to the engagement cost, \( t(52) = .39, p = .70, \) Cohen’s \( d = .11 \), while the disengagement cost was significantly higher in the dysphoric group compared to the non-dysphoric group, \( t(52) = -3.22, p = .002, \) Cohen’s \( d = .88 \). By comparison, results of within-group comparisons revealed that, for the non-dysphoric group, the engagement (neutral to angry) cost was significantly higher than the disengagement cost (angry to neutral), \( t(33) = 3.47, p = .001, \) Cohen’s \( d = .91 \). No significant differences between engagement and disengagement cost emerged in the dysphoric group, \( t(19) = -.55, p = .59, \) Cohen’s \( d = .12 \) (Figure 2B).

\[ ^3 \text{The three-way interaction is trend significant when excluding referred adolescents with low CDI scores from the non-dysphoric group, } F(1, 43) = 3.37, p = .073, \eta^2 = .03. \]
Figure 2. (A) Mean shift cost (RT shift trials minus RT repeat trials) and standard error of the mean in the emotion versus the gender condition for non-dysphorics and dysphorics. (B) Mean shift cost and standard error of the mean in the engagement (RT neutral-angry trials minus RT neutral-neutral trials) versus the disengagement (RT angry-neutral trials minus RT angry-angry trials) condition for non-dysphorics and dysphorics. *p < .05; **p ≤ .01; *** p < .001.
Discussion

The main goal of this study was to assess internal shifting impairments related to emotional and non-emotional information in dysphoric adolescents by adopting the IST (De Lissnyder, Koster, & De Raedt, 2012). Pertinent to the study hypotheses we found that: (1) dysphoric adolescents did not show general shifting impairments relative to unaffected adolescents; (2) the dysphoric group did experience specific shifting difficulties in the emotional condition of the task compared to the non-dysphoric group; and (3) while there were no significant group differences when shifting from neutral to negative information (i.e., engagement), dysphoric adolescents showed greater impairments when shifting from negative to neutral information (i.e., disengagement) compared to non-dysphoric adolescents.

In general, the results provide evidence for emotion-specific shifting impairments in dysphoric adolescents. Specifically, dysphoric adolescents only showed greater shifting impairments compared to non-dysphoric adolescents when emotional features of the presented pictures had to be processed, but not when non-emotional features were task-relevant. This corresponds to the results of previous cognitive control studies in dysphoric or depressed adolescents (e.g., Kyte et al., 2005; Ladouceur et al., 2006; Wante et al., 2015) and is in line with the idea that cognitive control processes are particularly hampered when processing emotional information (Joormann, Yoon, et al., 2007). The current results are also consistent with a study of Lo and Allen (2011) indicating an affective bias in internal shifting in depressed youth and multiple internal shifting studies among adults at risk for developing depression (De Lissnyder, Koster, Goubert, et al., 2012; Demeyer et al., 2012; Koster et al., 2013). The results further showed that non-dysphoric adolescents showed a trend significantly higher shift cost in the non-emotional condition (i.e., male vs. female faces) compared to dysphoric adolescents. This indicates that non-dysphoric adolescents do not perform better, and even perform slightly worse, in the non-emotional condition compared to dysphoric adolescents. This result clearly points to the absence of shifting impairments in response to non-emotional information in dysphoric adolescents and is consistent with a number of previous studies that failed to find general cognitive control deficits in depressed and dysphoric adolescents (Vilgis et al., 2015).

Noteworthy, however, the present findings contrast with earlier research using the IST in clinically depressed adults which provided evidence for general but no emotion-specific shifting impairments (De Lissnyder, Koster, Everaert, et al., 2012). Importantly,
our study included dysphoric adolescents, while adult studies often include depressed participants with a history of chronicity or multiple depressive episodes. Thus, a potential explanation for the discrepancy is that general cognitive control impairments are a feature of severe and chronic depression, while dysfunctional cognitive processing of emotional stimuli is already observed in mildly depressed individuals at risk for the development of more severe depressive episodes (Joormann & Gotlib, 2007). This idea is also supported by a study of Holler et al. (2014), which indicated lowered general set shifting in severely, but not in mildly, depressed adolescents.

Within-group analyses further revealed that while dysphoric adolescents showed a higher shift cost in the emotional condition (i.e., angry vs. neutral faces) compared to the non-emotional condition (i.e., male vs. female faces), the non-dysphoric group experienced a lower shift cost in the emotional condition versus the non-emotional condition. The latter finding, which points to a faster shifting response when processing emotional features in healthy adolescents, corresponds to the results of a prior IST study in adults (De Lissnyder, Koster, & De Raedt, 2012) and can be explained by the fact that the ability to quickly categorize and to flexibly shift attention towards and away from emotional expressions is important for adaptive social functioning and may have evolutionary significance by facilitating a prompt response to emotionally salient and threatening stimuli (De Lissnyder, Koster, & De Raedt, 2012; Lang, Bradley, & Cuthbert, 1990). This generally faster response to distinguish and shift between emotional information compared to neutral information was not observed in the dysphoric group and in fact, the opposite tendency was found. This clearly indicates that emotional processing is perturbed in dysphoric adolescents.

Further analyses of valence-specific effects in the emotional condition revealed no significant differences between both groups with regard to engagement or shifting from neutral to angry faces. Importantly, however, a higher disengagement cost was found in the dysphoric group relative to unaffected adolescents. In other words, dysphoric adolescents experienced greater difficulties in shifting away from angry faces compared to non-dysphoric adolescents. These results correspond to earlier studies in adults (e.g., Koster et al., 2011; Levens & Gotlib, 2010) and provide evidence for impaired attentional disengagement from negative faces in dysphoric adolescents. This finding also suggests that the dysphoric group experienced specific difficulties to direct attention away from emotional information (top-down, higher-order cognitive processing), instead of having an early attentional bias towards emotional information (i.e. early automatic processing).
By contrast, unaffected adolescents not only disengaged quicker from negative faces relative to dysphoric youths but also relative to their own engagement toward angry faces. Such an effect can be explained by the fact that disengaging from a negative stimulus is a natural emotion regulating response to change the emotional impact (Ochsner & Gross, 2005) and can thus be considered as a more automatic and adaptive process than engaging attention toward negative stimuli in healthy adolescents. The lack of such a differential effect in dysphoric youth could explain their tendency to negatively elaborate on negative information and their inability to redirect attention to neutral or more positive information (Jones, Siegle, & Thase, 2008).

The results of the present investigation may have important clinical implications since the inability to shift or to disengage attention from negative information may intensify negative emotional responses and hinder the use of adaptive ER strategies, such as cognitive reappraisal or positive refocusing (Joormann & D’Avanzato, 2010; Kovacs, Joormann, & Gotlib, 2008). In this context, targeting internal cognitive control over emotional stimuli may be a promising avenue for future depression prevention programs. Specifically, the ability to disengage attention from negative information during stressful events will also make it more easy to cognitively reappraise the situation and thereby decrease negative affect (Troy & Mauss, 2011). On this topic, research in depressed adults has already provided promising evidence for a significant effect of cognitive control training on ER and stress reactivity (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015).

The present study has several strengths. First, in contrast to the majority of previous cognitive control studies in depressed or dysphoric adolescents (Vilgis et al., 2015), our study included emotional stimuli, which enabled us to investigate both general and emotion-specific shifting impairments. Moreover, the IST adopted in this study included pictures of faces instead of verbal stimuli order to provide higher ecological validity (Bradley et al., 1997). Second, while the focus of previous work has mainly been on the cognitive control in relation to externally presented stimuli, the IST paradigm allows us to investigate internal cognitive control by assessing the ability to shift attention between mental presentations held in working memory. This may be a particularly relevant process to investigate in dysphoric individuals given the negative internal or self-focused attention that characterizes depression (Pyszczynski & Greenberg, 1987). Finally, studying underlying mechanisms in dysphoric youngsters is important, in part, because adolescence proves a critical period of vulnerability to depression and because of the elevated risk of a
depressive disorder in adulthood following first-onset depression in adolescence (Fombonne, Wostear, Cooper, Harrington, & Rutter, 2001). Moreover, while previous studies in depressed adults are limited by depression severity, recurrent episodes, and often prior pharmacological interventions, studying dysphoric adolescents enables us to have a clearer look at the baseline cognitive processes.

However, in interpreting the results of this study, several limitations should be acknowledged. First, we assessed depressive symptoms through a self-report questionnaire. Although the CDI is a reliable screening instrument (Kovacs, 1992), the use of a structured clinical interview is required to check the presence of a depressive disorder (Hien et al., 1998). Second, in contrast to multiple studies investigating the processing of sad information in depression or dysphoria (e.g., Hankin et al., 2010; Joormann, Talbot, & Gotlib, 2007; Kyte et al., 2005), the current study examined shifting impairments in relation to angry faces. Since sad faces were not included in our stimulus set, it was not possible to compare the effects of different types of negative stimuli or to determine whether the observed effects are stimulus-specific or relate to negative emotional stimuli in general. Third, a large number of participants were excluded due to accuracy rates near chance level (i.e., < 60%). Notably, the accuracy rates obtained in the present study, especially in the gender condition, are clearly lower compared to multiple previous studies in which an IST including adult faces was employed in adults and average accuracy rates ranged between 83 and 88% (e.g., De Lissnyder, Koster, & De Raedt, 2012; De Lissnyder, Koster, Everaert, et al., 2012; Demeyer et al., 2012). This incongruence may be explained by the different age groups studied (Zelazo & Carlson, 2012). Specifically, previous studies using an IST with emotional faces were conducted in adult samples (e.g., De Lissnyder, Koster, & De Raedt, 2012; De Lissnyder, Koster, Everaert, et al., 2012; Demeyer et al., 2012), while the current study tested internal shifting in a sample of young adolescents with a mean age of 12 years old. Interestingly, however, the accuracy rates in the current study are comparable with the studies of Lo and Allen (2011) and Beckwe, Deroost, Koster, De Lissnyder, and De Raedt (2014) in which an IST with verbal stimuli was used in youth and young adults. Therefore, an alternative explanation for the relatively low accuracy rates in the current study may be found in the type of stimuli included in the IST. In contrast to the first-mentioned studies using pictures of adult faces as target stimuli (e.g., De Lissnyder, Koster, & De Raedt, 2012; De Lissnyder, Koster, Everaert, et al., 2012; Demeyer et al., 2012), the present study used child faces and the study of Lo and Allen (2011) and Beckwe et al. (2014) used verbal stimuli, which may both be more
ambiguous compared to adult faces (Bradley et al., 1997; Wild et al., 2000). In line with this argument, a face recognition study of Wild et al. (2000) showed that both children and adults performed significantly less accurate in classifying children’s faces by gender compared to classifying adult faces. Based on these considerations, it can be concluded that future studies using the IST in children or adolescents are warranted to replicate the current findings. Moreover, these studies should consider the use of other stimuli (e.g., adult faces) or should provide more time for practice with feedback to explore whether these adjustments improve accuracy rates on the IST in general and in the non-emotional condition in particular.

Finally, it will be interesting to replicate this study on adolescents who are vulnerable to depression and previously depressed adolescents to explore if cognitive control plays a role in the development or recurrence of depression and not merely represents a symptom of depressed mood. In fact, if future longitudinal research continues to demonstrate the underlying role of maladaptive cognitive control processes, directly targeting these processes with computerized training tasks may improve the efficacy of standard prevention programs (Siegle, Ghinassi, & Thase, 2007).

**Conclusions**

In sum, dysphoric adolescents experienced specific shifting impairments when emotional features of the pictures had to be processed. Moreover, valence-specific analyses revealed greater difficulties shifting from angry to neutral faces relative to non-dysphoric adolescents, while there were no significant group differences when shifting from neutral to negative information. It will be important for future studies to investigate the association between internal shifting and adaptive ER. Moreover, longitudinal studies are needed to investigate shifting impairments in at risk-youngsters and adolescents previously diagnosed with depression to explore the role of internal cognitive control processes in the development and maintenance of depression.
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INTERNAL SHIFTING IMPAIRMENTS IN DYSPHORIC ADOLESCENTS

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Recapitulation of the Research Goals

The general aim of this doctoral dissertation was to investigate specific cognitive control processes and the influence of emotional information on these processes in adolescents suffering from depressive symptoms. Contemporary cognitive models of depression have proposed that deficits in basic cognitive control processes hinder the adequate regulation of affect, which in turn leads to the development or persistence of depressive symptoms (Joormann, Yoon, & Zetsche, 2007; Koster, De Lissnyder, Derakshan, & De Raedt, 2011). While a vast majority of studies in depressed adults demonstrated impairments on tasks tapping diverse executive functions (EF) such as working memory (WM), updating, shifting, and inhibition, findings in adolescents are variable with only a few studies indicating a clear difference between depressed and non-depressed groups (for a review see Vilgis, Silk, & Vance, 2015). Furthermore, recent studies suggest that cognitive control may be particularly hampered in the context of schema-congruent or negative emotional information (Gotlib & Joormann, 2010; Koster et al., 2011). Unfortunately, little research has investigated the effects of emotion on cognitive control performance in depressed adolescents and again results of these studies are inconclusive (for a review see Mueller, 2011). However, as adolescence is marked by ongoing cognitive and emotional maturation (Dahl, 2004) and an increased risk for developing depression (Hankin et al., 1998), additional research on cognitive control-emotion interactions in this age group is of major importance.

The first objective of the present dissertation was to explore the underlying role of emotion regulation (ER) in the link between cognitive control and depression. As recent cognitive models highlight that cognitive control impairments may lead to depressive symptoms through ER ability (Joormann & Vanderlind, 2014; Joormann et al., 2007; Koster et al., 2011), we conducted a questionnaire study on the mediating role of adaptive
and maladaptive ER strategies in the association between EF impairments, as measured with the Behavior Rating Inventory of Executive Functioning (BRIEF) questionnaire, and depressive symptoms in adolescents (Chapter 2). However, questionnaire results may pose interpretational problems as the everyday behaviors (i.e., planning and organizing) that are assessed may result from multiple cognitive and non-cognitive processes (Snyder, Miyake, & Hankin, 2015). Therefore, in the subsequent studies, performance-based EF tasks were used, providing an adequate and objective measure of three core EF components: working memory (WM), inhibition, and shifting (Diamond, 2013; Miyake et al., 2000).

In Chapter 3, an emotional n-back task was utilized to assess the influence of relevant and irrelevant emotional stimuli on WM in depressed and non-depressed adolescents. In the next study (Chapter 4), we aimed to replicate and extend Chapter 3’s findings regarding WM by using a memory-guided saccade task (MGST) in dysphoric and non-dysphoric adolescents. Saccadic eye movement tasks have the advantage of providing a precise and direct measure of cognitive control processes and have been shown to be a reliable and sensitive measure of EF in normative and clinical youth (Armstrong & Olatunji, 2012; Karatekin, 2007).

In the last two experimental studies, we shifted our focus from WM processes to two other key EF components: inhibition and shifting. In Chapter 5, we compared dysphoric and non-dysphoric adolescents’ performance on a Negative Affective Priming (NAP) task measuring interference and inhibition towards emotional information. Finally, in Chapter 6, our aim was to investigate internal cognitive control, and shifting between emotional and non-emotional mental sets in particular, by conducting an Internal Shifting Task (IST) in dysphoric and non-dysphoric adolescents. In contrast to the studies reported in Chapters 3 and 4, which included adult faces as emotional stimuli, the EF tasks used in the subsequent studies (Chapters 5 and 6) included emotional child faces (for an overview of the studies, see Figure 1).
Figure 1. An overview of the studies included in this dissertation. Note. RT = response times; EF = Executive Functioning.

Integration of the Main Findings

General Cognitive Control Impairments

Before diving into the influence of emotion on cognitive control processes, which is the main topic of the current thesis, it is worth discussing our results on general EF ability in depressed or dysphoric adolescents. As cognitive control is an important prerequisite for flexible and goal-directed behavior (Banich, 2009; Garon, Bryson, & Smith, 2008), deficits in this ability have been suggested to hamper adaptive ER and thereby increase the risk for developing depressive symptoms (Joormann & Vanderlind, 2014; Joormann, Yoon, & Siemer, 2010; Koster et al., 2011). While there is robust evidence for general cognitive control impairments in severely depressed adults (for a review see Ahern & Semkovska, 2017; Snyder, 2013), little is known about cognitive control ability in depressed or dysphoric adolescents and results of previous research have been mixed (for a review see Vilgis et al., 2015). Specifically, while some studies indicated
impaired cognitive control in adolescents with depressive symptoms (e.g., Han et al., 2016; Holler, Kavanagh, & Cook, 2014; Sommerfeldt et al., 2016), others failed to find significant group differences (e.g., Cataldo, Nobile, Lorusso, Battaglia, & Molteni, 2005; Constantinidou, Danos, Nelson, & Baker, 2011; Favre et al., 2009).

In the current thesis, partial evidence was found for the relationship between general cognitive control impairments (i.e., deficits in basic EF) and depressive symptoms in adolescents. In our questionnaire study (Chapter 2), we found that general EF impairments were positively related to depressive symptoms in a sample consisting of healthy, at-risk, and referred adolescents. Moreover, this association was partially mediated by an increased use of maladaptive ER strategies and a decreased use of adaptive ER strategies. The indirect effect of impaired EF on depressive symptoms through ER ability is in line with recent cognitive models and research (Gotlib & Joormann, 2010; Joormann & Vanderlind, 2014; Koster et al., 2011) and is consistent with a prospective study (Demeyer, De Lissnyder, Koster, & De Raedt, 2012), in which rumination mediated the association between cognitive control deficits and depressive symptoms at 1-year follow-up. Moreover, our findings are congruent with a recent study showing that coping is a mediating mechanism in the association between EF deficits and subsequent depressive symptoms in young adolescents (Evans, Kouros, Samanez-Larkin, & Garber, 2016).

The results of the emotional n-back study discussed in Chapter 3 also provided evidence for the association between general cognitive control impairments and adolescent depression. More concretely, a larger proportion of the depressed (13%) compared to the non-depressed group (1%) failed to reach a minimum accuracy rate of 60% on the practice trials of the 2-back or high WM load task. These results may point to general impairments in maintaining and updating information in WM and correspond to a recent meta-analysis, which suggests that depressed youth show deficits in various cognitive domains (Wagner, Muller, Helmreich, Huss, & Tadic, 2015). The current findings are also congruent with a small number of studies indicating general WM impairments in depressed adolescents (e.g., Bloch et al., 2013; Brooks, Iverson, Sherman, & Roberge, 2010; Matthews, Coghill, & Rhodes, 2008).

However, as opposed to the results of Chapters 2 and Chapter 3, the findings of the eye movement study measuring visuospatial WM (Chapter 4) indicated that accuracy rates of dysphoric adolescents did not significantly differ from non-dysphoric adolescents. Likewise, the results Chapters 5 and 6, which focused on two other core EF components
(inhibition and shifting respectively), did not indicate general cognitive control deficits in adolescent dysphoria. First, the affective priming study (Chapter 5) demonstrated a higher inhibition of emotional information in dysphoric as compared to non-dysphoric adolescents. Although a NAP task is not designed to measure general cognitive control as it does not include a non-emotional condition, these results do not suggest general inhibitory deficits. Next, our findings regarding internal shifting (Chapter 6) indicated no impairments in shifting between non-emotional mental representations in dysphoric adolescents and correspond to previous results on general shifting ability in depressed adolescents (Evans et al., 2016; Favre et al., 2009; Han et al., 2016). Worthy of note, however, is that the present results contrast with a previous internal shifting study, which demonstrated significant general shifting impairments in depressed versus non-depressed adults (De Lissnyder et al., 2012).

A potential explanation for the diverging results of the first study (Chapter 2) and the three last experimental studies (Chapters 4-6) conducted in this thesis can be found in the use of different measures to assess EF. While Study 1 (Chapter 2) used the BRIEF questionnaire to assess behaviors related to general EF, the subsequent studies used experimental EF tasks which provided an objective measure of specific EF components (WM, inhibition, and shifting). Despite the fact that questionnaires are considered to be an ecologically valid measure of EF, they only provide a rough measure of everyday EF and cannot be assumed to measure the same constructs as experimental tasks (Snyder et al., 2015; Toplak, West, & Stanovich, 2013).

Furthermore, several other factors may have contributed to the contradictory results of the experimental chapters (Chapter 3-6). First, the failure of the MGST study (Chapter 4) to replicate general WM impairment as reported in the emotional n-back study (Chapter 3) could be due to the fact that the tasks tap different WM processes, namely maintenance (MGST) versus updating (emotional n-back task). Updating is considered the most demanding of the two processes since it requires maintenance and transformation of information in WM, while maintenance does not require transformational processes (Schmeichel, 2007). Hence, it is likely that depression is specifically associated with problems in updating as it relies on more executive involvement and prefrontal cortex (PFC) activity than maintenance (D'Esposito & Postle, 1999; Luciana, Conklin, Hooper, & Yarger, 2005). In addition, the tasks differ in response modality (manual responses in emotional n-back vs eye movements in MGST), which may have activated different subcortical regions and may thus explain differences in WM results.
Another reason for incongruent results between the experimental chapters may be the focus on different cognitive control functions. Specifically, in Chapters 5 and 6 the focus was switched from WM processes (Chapters 3, 4) to inhibition and shifting processes. Previous work on EF has provided evidence that these three key cognitive control components are moderately correlated but still are clearly distinct from one another (Diamond, 2013; Miyake et al., 2000). Moreover, these functions show different developmental trajectories throughout childhood and adolescence (Best & Miller, 2010). For instance, studies on the maturation of cognitive processes from late childhood to adulthood indicated that inhibition and shifting undergo a marked improvement during preschool and primary school years respectively and reach adult levels at the age of 14 to 15 years (Huizinga, Dolan, & van der Molen, 2006; Luna, Garver, Urban, Lazar, & Sweeney, 2004). In contrast, WM ability gradually continues to develop until the twenties, especially for more demanding tasks that require both the maintenance and manipulation of information (Conklin, Luciana, Hooper, & Yarger, 2007). The relatively late development of WM, and updating in particular, may explain why dysphoric adolescents only show general impairments on the emotional n-back task measuring WM updating (Chapter 3), and not on those measuring WM maintenance (Chapter 4), inhibition (Chapter 5), or shifting (Chapter 6).

Further, the heterogeneity of results could be attributed to differences in depression severity. More concretely, the emotional n-back study (Chapter 3) included referred adolescents diagnosed with Major Depressive Disorder (MDD), while the other experimental studies (Chapters 4-6) included dysphoric adolescents suffering from mild to severe depressive symptoms. Indeed, the level of cognitive control impairments may be dependent on depression symptom severity and clear deficits may thus only arise in clinically depressed adolescents whose cognitive resources are significantly reduced compared to dysphoric adolescents at risk for developing MDD (Harvey et al., 2004; Joormann & Gotlib, 2007).

Finally, it has to be acknowledged that the inconclusive results of the current thesis in dysphoric adolescents are opposite to the robust evidence for impairments of various EF components in depressed adults (for a review see Snyder, 2013). Sample characteristics may be the basis of this discrepancy. First, our studies that failed to find general cognitive deficits included adolescents with (sub)clinical levels of depression (Chapter 4-6), while adult studies often include depressed individuals with a history of chronic depression. As the accumulation of depressive episodes may leave profound
cognitive “scars” and increasingly deplete cognitive resources (Vanderhasselt & De Raedt, 2009), cognitive control is likely to be more damaged in (chronically) depressed adults compared to dysphoric adolescents. Furthermore, the incongruence may be due to developmental differences between adolescent and adult samples. Adolescence, as compared to adulthood, is a developmental period in which the brain, and the PFC in particular, still undergoes prominent changes which contribute to cognitive control ability and improve complex EF processes (Best & Miller, 2010; Spear, 2000).

**The Influence of Emotional Stimuli on Cognitive Control Processes**

It is clear that prior research attempts to demonstrate general cognitive control impairments in depressed adolescents were equivocal (for a review see Vilgis et al., 2015). Since depression is typically characterized by a perseverative focus on negative thoughts and feelings (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008), it is of major relevance to investigate whether cognitive control deficits are more pronounced in the context of emotional information. Specifically, depressed individuals are assumed to preferentially process and be easily distracted by schema-congruent information, even when irrelevant to the goal or task at hand (Joormann et al., 2007; Koster et al., 2011). Despite growing evidence in depressed adults, the interaction between emotion and cognitive control processes received scant empirical attention in younger age samples (for a review see Mueller, 2011). Therefore, the central aim of the experimental chapters (Chapters 3-6) of this thesis was to explore the effect of emotional stimuli on three core EF components (WM, inhibition, shifting) in adolescents suffering from depressive symptoms.

Curiously, two patterns of results emerged in depressed/dysphoric adolescents, with one indicating unaffected cognitive control performance in the context of emotional information, while the other showed a deleterious effect of negative emotion on cognitive control (for an overview of the results, see Table 1).
Table 1. Summary of the main findings per study

<table>
<thead>
<tr>
<th>Task</th>
<th>Load</th>
<th>Sample</th>
<th>EF</th>
<th>Stimuli</th>
<th>Relevance of emotion</th>
<th>Presentation</th>
<th>Modality</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavior Rating Inventory of EF</td>
<td>/</td>
<td>Healthy, at-risk, &amp; referred adolescents</td>
<td>Everyday EF</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>Indirect effect of impaired EF on adolescent depressive symptoms through ER ability</td>
</tr>
<tr>
<td>N-back</td>
<td>HL &amp; LL</td>
<td>Depressed vs. non-depressed</td>
<td>WM</td>
<td>Neutral, happy, &amp; angry adult faces</td>
<td>Task-relevant &amp; task-irrelevant</td>
<td>Relevant &amp; irrelevant information within same stimulus</td>
<td>Manual</td>
<td>Larger proportion of the depressed group failed to reach a minimum accuracy of 60% on practice blocks of the HL WM task</td>
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<td></td>
<td>In depressed group: no effect of emotional stimuli on WM</td>
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<td></td>
<td>In non-depressed group: effect of happy faces on WM in HL condition</td>
</tr>
<tr>
<td>Memory-Guided Saccade Task</td>
<td>HL &amp; LL</td>
<td>Dysphoric vs. non-dysphoric</td>
<td>WM</td>
<td>Neutral, happy, &amp; angry adult faces</td>
<td>Task-irrelevant</td>
<td>Relevant &amp; irrelevant information within same stimulus</td>
<td>Eye movements</td>
<td>In dysphoric group: no effect of irrelevant emotional stimuli on WM</td>
</tr>
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<td></td>
<td>In non-dysphoric group: effect of irrelevant angry faces on WM in HL trials</td>
</tr>
</tbody>
</table>

Note. EF = executive function(ing); ER = emotion regulation; HL = high load; LL = low load; WM = working memory; RT = response time
**Table 1 (continued).** Summary of the main findings per study

<table>
<thead>
<tr>
<th>Task</th>
<th>Load</th>
<th>Sample</th>
<th>EF</th>
<th>Stimuli</th>
<th>Relevance of emotion</th>
<th>Presentation</th>
<th>Modality</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative Affective Priming Task</td>
<td>Dyshoric vs. nondysphoric</td>
<td>Interference &amp; inhibition</td>
<td>Neutral, happy, &amp; angry child faces</td>
<td>Task-relevant &amp; task-irrelevant information in separate stimuli (target and distractor stimuli)</td>
<td>Relevant &amp; irrelevant information in separate stimuli (target and distractor stimuli)</td>
<td>Manual</td>
<td></td>
<td>In dysphoric group: higher interference/inhibition of angry distractor faces Both groups: no effect of happy distractor faces + correlation between interference and inhibition</td>
</tr>
</tbody>
</table>

| Internal Shifting Task     | Dyshoric vs. nondysphoric | Shifting in WM | Neutral & angry child faces | Task-relevant & task-irrelevant information within same stimulus | Relevant and irrelevant information within same stimulus | Manual       |          | Based on RT In dysphoric group: greater shifting impairments when processing emotional information (mainly disengagement from angry – neutral) |

*Note.* WM = working memory; RT = response time
**Unaffected cognitive control and blunted emotional reactivity.** The findings of Chapters 3 and 4 indicated that WM was unaffected by the presence of emotional stimuli in adolescents with depressive symptoms. In our emotional n-back study (Chapter 3), performance of depressed adolescents was *not* influenced by the presence of relevant or irrelevant emotional faces. Performance of non-depressed adolescents, however, was clearly influenced by the presence of happy faces in the high load WM condition (i.e., 2-back task). More specifically, happy faces led to faster response times (RTs) in the valence or emotion-relevant condition and to slower RTs in the gender or emotion-irrelevant condition. These findings suggest that depressed adolescents lack a normative memory bias towards positive information. This is broadly in line with theory (Alloy & Abramson, 1988; Alloy, Albright, Abramson, & Dykman, 1990) and research stating that depressed and dysphoric individuals show an even-handed processing and memory of positive and negative information (e.g., Gilboa, Roberts, & Gotlib, 1997; McCabe & Toman, 2000; Timbremont & Braet, 2004), whereas healthy adolescents display self-enhancing or positivity biases (Cromheeke & Mueller, 2015; Ladouceur et al., 2005).

Similar results were obtained in the saccadic eye movement study reported in Chapter 4. Here, latency analyses revealed *no* effects of emotional distractor faces on WM performance in dysphoric adolescents. In contrast, angry distractor faces slowed performance of non-dysphoric adolescents in the high WM load condition (i.e., remembering location of 4 colored stimuli). This finding in healthy adolescents fits into the “threat relevance framework”, which suggests that threat-relevant information (e.g., angry faces, snakes) attracts attention and elicits an orienting reflex to evaluate the level of danger (e.g., Kindt, van den Hout, de Jong, & Hoekzema, 2000; Lobue & DeLoache, 2008; Ohman & Mineka, 2001). This automatic “threat-evaluation” may explain their slower latencies for stimuli overlaid with irrelevant angry faces. Furthermore, the accuracy analyses revealed that happy distractor faces improved WM performance in non-dysphoric adolescents (i.e., lower error rates), while this was not the case in dysphoric adolescents. Worthy of note is that this emotion by group interaction on accuracy data became trend significant when we adjusted for comorbid anxiety symptoms, suggesting that these group differences may be driven by co-occurring anxiety symptoms. Nevertheless, this finding points in the same direction as the results obtained on the emotional n-back task and indicates a positivity bias or a better memory for stimuli overlaid with happy faces in healthy adolescents.
The findings of Chapters 3 and 4 jointly provide evidence for blunted emotional reactivity in the context of WM in adolescents with elevated depressive symptoms. These results neither coincide with recent cognitive models (De Raedt & Koster, 2010; Joormann et al., 2007; Koster et al., 2011) nor adult literature (for a review see Snyder, 2013) postulating that depressed individuals experience cognitive control impairments when presented with irrelevant negative emotional information. Interestingly, however, this pattern of results is largely consistent with the Emotion Context Insensitivity (ECI) model of depression (Rottenberg & Gotlib, 2004; Rottenberg, Gross, & Gotlib, 2005), which suggests that depressed individuals are characterized by alterations in amygdala-prefrontal cortex connectivity and experience diminished emotional reactivity towards positive and negative emotional stimuli (Figure 2, left panel). Drawing on evolutionary theories (Nesse, 2000), the EIC model posits that a depressed mood may have originally evolved as a defensive response in adverse circumstances and provokes reduced reactivity to novel emotional stimuli. This blunted emotional reactivity is considered to play a key role in the impaired psychosocial functioning and emotion dysregulation that characterizes individuals with depression (Rottenberg, Kasch, Gross, & Gotlib, 2002). Supportive evidence for the EIC model has already been obtained in several behavioral, physiological, and neuroimaging studies on emotional reactivity in depressed adults (Dichter & Tornarken, 2008; Foti, Olvet, Klein, & Hajcak, 2010; Rottenberg et al., 2005).

Regarding cognitive performance of healthy adolescents, the results in Chapters 3 and 4 demonstrated a clear bias towards emotional stimuli, but only in the high load WM condition of the tasks. This corresponds to the Attentional Control Theory (ACT; Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007), which states that emotions and emotional stimuli will particularly affect EF processes when cognitive load is high. Specifically, tasks with high cognitive demands, as compared to tasks with low cognitive demands, require a substantial amount of cognitive resources, leaving individuals with insufficient resources to inhibit or compensate effects of evocative emotional stimuli on performance. A recent study provided evidence for this theory by showing effects of emotion on performance in WM tasks with high demands (or high load WM tasks) but not in WM tasks with low demands (or low load WM tasks) (Li, Ouyang, & Luo, 2012).
Figure 2. An illustration of the basic ideas of the Emotion Context Insensitivity Model (left panel) and the Impaired Attentional Disengagement framework (right panel).
Bias towards schema-congruent information and impaired disengagement. Directly contrasting the abovementioned pattern of results, Chapters 5 and 6 demonstrated a bias towards negative information among dysphoric adolescents. First, the affective priming study (Chapter 5) indicated that dysphoric adolescents experience a higher interference and show a higher inhibition of angry child faces relative to healthy adolescents. The findings also revealed a correlation between interference and the inhibition of a negative emotional stimulus. Together these results suggest that dysphoric adolescents were more easily distracted by angry faces and subsequently inhibited them more. Our NAP findings replicate the results of a couple of prior affective priming studies conducted on dysphoric students indicating greater interference and an elevated inhibition of negative distracting words (Gotlib, Yue, & Joormann, 2005) and angry faces (Zetsche & Joormann, 2011). However, these findings contradict several studies that used a similar NAP task in depressed adults and found less inhibition of negative emotional information (Goeleven, De Raedt, Baert, & Koster, 2006; Joormann, 2004). Differences in the emotional stimuli that have been used in various affective priming tasks may be the origin of this incongruence. For instance, previous studies in depressed adults often employed sad faces as emotional distractor stimuli (e.g., Goeleven et al., 2006; Kyte, Goodyer, & Sahakian, 2005; Levens & Gotlib, 2010; Maalouf et al., 2012), whereas our NAP study relied on angry faces. As angry faces may activate depressogenic schemas of social rejection, they may be highly disturbing and thus provoke strong inhibitory responses (Gilboa-Schechtman, Ben-Artzi, Jeczemien, Marom, & Hermesh, 2004; Hames, Hagan, & Joine, 2013). Sad faces, however, are mood-congruent and may be considered less salient and disturbing for depressed individuals. Furthermore, depression severity of the studied samples may have some explanatory value. Specifically, lower inhibition of negative information is mostly found in adults with a diagnosis of (recurrent) depression (Goeleven et al., 2006; Joormann & Gotlib, 2010), while elevated inhibition is apparent in dysphoric samples (Gotlib et al., 2005; Zetsche & Joormann, 2011). It can thus be hypothesized that cognitive resources (or ability to deal with emotional interfering stimuli) significantly diminish with increasing depressive episodes (De Raedt & Koster, 2010; Vanderhasselt & De Raedt, 2009).

Next, the results on internal shifting (Chapter 6) provided evidence for emotion-specific shifting impairments in dysphoric adolescents. We specifically found that dysphoric adolescents, as compared to non-dysphoric adolescents, experienced a higher shift cost when emotional information (i.e., emotional expression of a face) had to be
attended in the IST. This supports the idea that cognitive control, and shifting in particular, in response to negative emotional information is already impaired in mildly depressed individuals, who are at risk for developing more severe forms of depression (Demeyer et al., 2012; Holler et al., 2014; Joormann & Gotlib, 2007). Interestingly, further analyses on valence-specific effects revealed that dysphoric adolescents had specific difficulties with disengaging their attention from angry to neutral faces (top-down, higher-order cognitive processing), rather than engaging their attention towards angry faces (early automatic processing). These results correspond to theory and research suggesting impaired attentional disengagement from negative information in depression (De Raedt & Koster, 2010; Demeyer et al., 2012; Joormann & D’Avanzato, 2010; Koster et al., 2011).

In sum, the findings of these chapters indicate perturbed cognitive processing of negative information in dysphoric adolescents. Specifically, it can be assumed that dysphoric adolescents are highly disturbed by the presence of negative child faces that are irrelevant to the task and therefore inhibit these stimuli to a greater extent than healthy adolescents (Chapter 5). In addition, when a task requires active processing of and flexible shifting between emotional mental representations in WM (Chapter 6), dysphoric adolescents, relative to healthy adolescents, appear to have greater difficulties with shifting, and disengaging their attention away from negative information in particular. These findings are largely in line with recent cognitive models (De Raedt & Koster, 2010; Koster et al., 2011), which state that depressed individuals prioritize the processing of schema-congruent negative information at the cost of adequate cognitive control performance (Figure 2, right panel). Specifically, it is suggested that depressed individuals have difficulties disengaging attention from (irrelevant) negative stimuli, which leads to prolonged elaboration of this emotional information and hampers adequate ER, such as reappraising the situation or distracting oneself.

**Towards a better understanding of conflicting results.** It is clear that the studies in the current doctoral thesis provided conflicting results regarding the influence of emotion on cognitive control processes. The results of the first two experimental studies on WM (Chapters 3 and 4) demonstrated diminished reactivity to emotional stimuli and unaffected WM performance in depressed and dysphoric adolescents. In contrast, the findings discussed in Chapters 5 and 6 revealed elevated inhibition and impaired shifting in response to negative emotional faces in the dysphoric group (see Figure 3 for an integration of the findings).
Figure 3. An integration of the key findings of the dissertation. Note. WM = working memory
The fact that emotional information only had an influence on cognitive control in the last two studies (Chapters 5 and 6) and not in the first experimental studies (Chapters 3 and 4) may be due to the types of stimuli that have been used (child vs adult faces). Specifically, emotional child faces (used in Chapters 5 and 6) can be considered highly intense and personally relevant as adolescence is a developmental phase in which peer relations (e.g., having friends, being liked by peers) are of great importance for emotional well-being and self-esteem (La Greca & Harrison, 2005; Litwack, Aikins, & Cillessen, 2012; Zimmer-Gembeck, Geiger, & Crick, 2005).

Moreover, it is likely that angry child faces trigger depression-related schemas of social rejection (Beck, 1983; Hames et al., 2013) and therefore evoke strong emotional reactions and significantly impact cognitive control processes in dysphoric adolescents (Figure 3; pathway 2). In contrast, emotional adult faces (Chapters 3 and 4) can be seen as mildly to moderately intense emotional stimuli that attract attention to a lesser extent and fail to evoke a (normative) emotional response in depressed or dysphoric adolescents (i.e., blunted emotional reactivity) (Figure 3; pathway 1). It can thus be hypothesized that the impact of an emotionally-laden stimulus on cognitive control performance in depressed or dysphoric adolescents depends on its relevance and the degree to which it activates depressogenic schemas (Beck, 1983; Rottenberg et al., 2005). This idea fits within the dual-competition framework of Pessoa (2009), which states that highly intense or relevant stimuli (e.g., angry child faces) will receive prioritized processing and influence or disturb performance on a cognitive control task, whereas mildly intense or relevant stimuli (e.g., angry adult faces) do not attract attention and only have a weak effect on behavior.

Furthermore, the obtained results suggest that emotional stimuli may particularly impair the shifting component of cognitive control in dysphoric adolescents. More specifically, depressed and dysphoric adolescents show unaffected cognitive control on EF tasks requiring the processing of (emotional) information in WM (Chapters 3 and 4) and higher cognitive control on tasks requiring the inhibition of irrelevant emotional information (Chapter 5). In contrast, dysphoric adolescents performed worse on a cognitive task requiring rapid and flexible shifting between emotional mental sets in WM, with particular difficulties disengaging attention from negatively-valenced information (Chapter 6). These findings correspond to the “mental inflexibility view”, which postulates that the typical tendency of depressed or dysphoric individuals to become cognitively and affectively stuck (e.g., rumination, emotional inertia) may counterintuitively lead to unaffected or “better” performance in cognitive control tasks that
require active goal maintenance despite the presence of (task-irrelevant) emotional stimuli (Altamirano, Miyake, & Whitmer, 2010; Goschke, 2000; Koval, Kuppens, Allen, & Sheeber, 2012) (cf. Chapters 3-5). Indeed, their tendency to “get stuck” mentally and emotionally may improve their ability to keep goals or information active in WM. However, when a task requires rapid shifting between mental sets, their inflexibility is disadvantageous and may impede the ability to shift attention from negative information to more positive or neutral information (cf. Chapter 6; Figure 3, dotted frame). An interesting study on this topic is that by Altamirano et al. (2010), who found that individuals with high ruminative tendencies performed better on tasks requiring goal maintenance and worse on tasks requiring rapid shifting compared to individuals with low ruminative tendencies.

Importantly, although the results of the current thesis point in different directions with regard to the influence of emotion on cognitive control, it can be hypothesized that the altered emotional processing (blunted or increased emotional reactivity), as well as the cognitive inflexibility that characterizes depressed/ dysphoric adolescents hampers adequate ER (Altamirano et al., 2010; Koster et al., 2011; Rottenberg et al., 2005). Specifically, based on the results of Chapter 2, we may assume that this affective and cognitive inflexibility hinders the use of adaptive ER strategies (e.g., cognitive reappraisal) and stimulates the use of maladaptive ER strategies (i.e., rumination), which in turn further increases depressive symptoms and the risk of developing clinical depression.

Clinical Implications

Both at theoretical and clinical levels, our results may contribute to a better understanding of how cognitive control impairments are involved in adolescent depression. Although not the main focus of the current thesis, the results concerning general cognitive control indicate that impairments are most apparent in broad everyday EF behaviors (e.g., planning, organizing; Chapter 2) and tasks requiring relatively complex WM operations, such as an emotional n-back task (Chapter 3), whereas no deficits emerge in other specific cognitive functions, such as WM maintenance and shifting (Chapter 4-6). This contrasts with earlier research showing impairments on all key EF components in depressed adults (for a review, Snyder, 2013) and suggests that prefrontal functioning and cognitive control increasingly deteriorate over time and across depressive episodes (De Raedt & Koster, 2010). In this respect, future studies exploring cognitive control ability across age groups (adolescents vs. adults), when taking into
account the number of past depressive episodes and symptom severity, would enable to pinpoint the moment at which prefrontal functioning clearly goes off course and cognitive control training would be most beneficial. Worthy of note is that research in adults already provided evidence for a significant effect of cognitive control training targeting WM on ER and stress reactivity (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015; Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013; Siegle, Ghinassi, & Thase, 2007). However, parallel research in depressed or dysphoric adolescents is currently lacking.

As for the interaction between emotion and cognitive control, the findings are rather diverse, but all point to a form of “cognitive rigidity” in response to emotional information in adolescents with elevated depressive symptoms. Specifically, dependent on the task being used and the EF being targeted, depressed and dysphoric adolescents show blunted reactivity to positive and negative stimuli (Chapters 3 and 4), or increased inhibition of irrelevant negative stimuli (Chapter 5) and impaired disengagement from relevant negative stimuli (Chapter 6). Consequently, a promising avenue for future research is to explore whether an ‘affective’ cognitive control training, specifically tailored to enhance flexibility in response to emotional stimuli, promotes ER and reduces depression vulnerability in adolescents. Interestingly, a review of Wadlinger and Isaacowitz (2011) indicated that attentional allocation processes, such as disengagement from negative stimuli and flexibly (re)orienting towards positive stimuli, can be trained through extensive practice and demonstrated positive effects of various attentional training programs on individuals’ ER ability. Unfortunately, the research included in this review focused on adult populations and cannot be simply extrapolated to children and adolescents.

As the impact of emotional stimuli on cognitive control seems to depend on various factors (e.g., type of emotional stimulus, specific EF processes) and as research on the effects of affective cognitive control interventions on ER and depression risk in adolescents is currently lacking, the most interesting direction for current prevention and research programs is to focus on compensatory strategies (Snyder et al., 2015). Based on the results of the questionnaire study reported in Chapter 2 and prior evidence in adults (Demeyer et al., 2012; Joormann, 2010; Joormann & Vanderlind, 2014), adequate and flexible ER may be an important tool to compensate for the dysfunctional cognitive processes that characterize adolescents with depressive symptoms. Specifically, programs focusing on improving the use of adaptive ER strategies (e.g., cognitive reappraisal, distraction), as well as reducing the use of maladaptive ER strategies (i.e., rumination, ...
suppression) may increase the capacity of adolescents to deal with emotional stress and indirectly improve cognitive and affective flexibility. This potentially important role of ER in the prevention of depression, combined with the scarcity of research in adolescents, stimulated our research team to develop an ER training for early adolescents and to investigate its effects on positive and negative affect states and broader mental health outcomes. The findings indicated that the use of specific ER strategies (i.e., cognitive reappraisal, distraction, acceptance, and problem solving) can be trained in this age group and has beneficial effects on positive and negative affect (Wante, Van Beveren, Theuwis, & Braet, in press). Although these results are promising, it is crucial for future research to replicate these findings in at-risk or currently depressed adolescents and to directly explore the impact on cognitive and affective flexibility.

**Limitations and Directions for Future Research**

Several limitations should be considered when interpreting the findings of the presented studies. First of all, there is the problem of task impurity. Although the behavioral tasks used in the current dissertation are designed to measure specific EF components and were picked carefully in terms of validity and reliability, it is likely that they tap multiple EF and non-EF processes. It is generally assumed that key EF aspects share a common component, namely the active maintenance of task-relevant information or goals in WM, but also require specific (e.g., updating-specific, shifting-specific) abilities (Miyake & Friedman, 2012; Miyake et al., 2000). Hence, performance on tasks targeting a particular EF component may be attributed to common EF ability, specific EF ability, and/or non-EF processes, such as perception and processing speed. Future research interested in specific EF impairments could address this limitation by including multiple tasks to measure one particular EF component, while also administering other tasks, in order to demonstrate specific deficits (Snyder et al., 2015).

A second limitation is the relatively small sample size of the experimental studies, which may have constrained the power of detecting clear group differences and thus may have mistakenly lead to null findings. In addition, power may have been reduced by including (mainly) dysphoric adolescents with mild to severe depressive symptoms instead of adolescents with a depressive disorder according to DSM-5 criteria. Although it has been increasingly recognized that it is particularly relevant to measure youth depression along a continuum of severity (Wesselhoeft, Sorensen, Heiervang, & Bilenberg, 2013), reliability and sensitivity of EF tasks may be lower in mildly to
moderately impaired individuals. Therefore, it appears important for future studies to conduct power analyses to estimate the sample size required for an expected effect size and to determine whether particular EF tasks have sufficient reliability and sensitivity to justify their use in a specific (subclinical) target population (Snyder et al., 2015).

The studies in the present dissertation are further limited by the cross-sectional nature of their design preventing conclusions about causal relationships between cognitive impairments and depression. Future prospective studies are needed to explore whether altered cognitive control-emotion interactions play a role in the development or recurrence of depression and not merely represent a symptom of depressed mood. Moreover, such studies may reveal whether ER ability has an explanatory role in the prospective relationship between cognitive control deficits and depression and may have important implications for prevention and early intervention programs. Specifically, if there is robust evidence for an underlying role of cognitive control processes and ER in depression, it is of great relevance to provide at-risk youth with a computerized ‘affective’ cognitive control training or at least with a training in complementary ER strategies before the onset of clinical depression (Siegle et al., 2007; Snyder et al., 2015).

A final limitation is related to the selection of negative emotional stimuli. In contrast to most previous studies that focused on the influence of sad stimuli (e.g., Goeleven et al., 2006; Kyte et al., 2005; Levens & Gotlib, 2010; Maalouf et al., 2012), the current thesis examined depression-related cognitive control processes in response to angry facial expressions. Although sad and angry stimuli are both negatively valenced, they may trigger different responses in depressed individuals. While sad faces are mood-congruent and may be considered familiar and not threatening, angry faces may be more intense and activate schemas of social rejection (Gilboa-Schechtman et al., 2004; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Hames et al., 2013). Hence, we would recommend future research to include both sad and angry information to determine whether the effects on cognitive control are stimulus-specific or relate to negative emotional stimuli in general.

**Final Conclusion**

The main objective of this thesis was to examine the impact of emotion on cognitive control processes in adolescents with depressive symptoms. A first study using a behavior rating scale of everyday EF documented that ER processes partially mediate the relationship between EF impairments and depressive symptomatology in adolescents.
Specifically, higher EF deficits were associated with a higher use of maladaptive ER strategies and a lower use of adaptive ER strategies, which in turn increases depressive symptoms. The subsequent studies focused on the influence of emotional stimuli on specific cognitive control components and results pointed in different directions. More concretely, based on WM paradigms including pictures of adult faces, it appears that depressed and dysphoric adolescents experience a blunted emotional reactivity towards positive and negative information. However, affective priming and shifting paradigms including pictures of child faces indicated that negative social information is highly interfering for dysphoric adolescents and evokes strong inhibitory responses when irrelevant and shifting or disengagement difficulties when relevant. These varying results indicate that including multiple tasks to measure one specific EF component in both depressed and dysphoric adolescents, as well as manipulating and systematically comparing a number of task factors (e.g., adult vs child faces; task-relevant vs task-irrelevant emotional stimuli) is highly recommended for future work. Clinically, these findings suggest impaired cognitive flexibility in response to emotional information in adolescents suffering from depressive symptoms. However, future research is necessary to replicate our findings and extend our results by, for example, conducting cognitive control tasks with different kinds of negative stimuli in currently depressed, remitted, and high-risk youth. Moreover, future longitudinal studies can clarify whether deficits in ‘emotional’ cognitive control represent a risk factor, a symptom, or a consequence of adolescent depression. Based on the current knowledge, an important avenue for future studies is to test the effects of a training targeted at cognitive flexibility in at-risk or currently depressed adolescents. In addition, future prevention and early intervention programs may benefit from focusing on teaching youth complementary strategies to deal with cognitive and affective inflexibility, such as adaptive ER strategies.
References


Depressie is een ernstige mentale aandoening die wereldwijd meer dan 300 miljoen mensen treft en gepaard gaat met symptomen zoals een neerslachtige stemming, prikkelbaarheid en verlies aan interesse en motivatie (AACAP, 2007; APA, 2013). Depressieve symptomen kennen vaak een chronisch verloop en zijn geassocieerd met een veelheid aan negatieve gevolgen, zoals verstoorde sociale relaties en schoolse moeilijkheden (AACAP, 2007). Hoewel depressie eerder zeldzaam is bij kinderen, stijgt de ‘lifetime’ prevalentie van een depressieve stoornis tot meer dan 10% tijdens de adolescentie en jongvolwassenheid (Costello, Erkanli, & Angold, 2006; Kessler & Walters, 1998). Daarenboven blijkt uit een grootschalige Europese studie aan dat bijna 30 procent van de adolescenten kampt met dysfornie of subklinische depressieve symptomen (Balazs, 2013). Naast deze alarmerende prevalentiecijfers, is het duidelijk dat zowel klinische als subklinische depressieve symptomen bij adolescenten de kans op自杀 substantieel verhogen en voorspellend zijn voor terugkerende en nog ernstigere depressieve episodes op volwassen leeftijd (Fombonne, Wostear, Cooper, Harrington, & Rutter, 2001; Pine, Cohen, Cohen, & Brook, 1999). Deze feiten beklemtonen dat depressieve symptomen bij adolescenten niet geminimaliseerd of ontkend mogen worden en dat verder onderzoek naar de onderliggende mechanismen van depressie in deze leeftijdsgroep van onmiskenbaar belang is.

Volgens de alom bekende en invloedrijke cognitieve theorie van Beck staan negatieve schema’s en informatieverwerkingsfouten centraal in de ontwikkeling en het voortbestaan van depressieve symptomen (Beck, 1967, 1976; Clark, Beck, & Alford, 1999). Verder bouwend op deze theorie, suggereren recente cognitieve modellen dat disfunctionele cognitieve controle processen een belangrijke rol spelen bij depressie en waarschijnlijk aan de grondslag liggen van de emotieregulatieproblemen die depressieve individuen ervaren (De Raedt & Koster, 2010; Joormann, Yoon, & Zetsche, 2007; Koster, De Lissnyder, Derakshan, & De Raedt, 2011). Cognitieve controle is een veelomvattende term voor executieve functies (EF) die zich bevinden in de prefrontale cortex van de hersenen en noodzakelijk zijn voor flexibel en doelgericht gedrag (Banich, 2009; Garon, Bryson, & Smith, 2008). Hoewel heel wat cognitieve vaardigheden onder de noemer EF vallen, worden shiften tussen taken of mentale sets, inhibitie van dominante responsen of irrelevante stimuli, en het vasthouden en updaten van informatie
in het werkgeheugen als de drie kern EF naar voor geschoven (Diamond, 2013; Miyake et al., 2000).

Ondanks dat steeds meer studies bij depressieve volwassenen (Miyake et al., 2000) evidentie vinden voor moeilijkheden op vlak van cognitieve controle en specifieke EF processen zoals inhibitie, werkgeheugen en verbale vlotheid (for a review see Ahern & Semkovska, 2017; Snyder, 2013), is er tot op heden relatief weinig onderzoek gebeurd bij jongere populaties. Bovendien zijn de resultaten van studies bij adolescenten niet eenduidig en tonen slechts een beperkt aantal studies duidelijke verschillen aan tussen depressieve en doorsnee jongeren wat betreft hun cognitieve controle vaardigheden (voor een review zie Vilgis, Silk, & Vance, 2015).

Aangezien onderzoek naar algemene cognitieve controle (i.e., taken met neutrale stimuli) gemengde resultaten oplevert, kan verondersteld worden dat onderzoek naar cognitieve controle in de context van emotionele stimuli meer eenduidige bevindingen zal opleveren (Vilgis et al., 2015). Specifiek kan verwacht worden dat depressieve individuen, die doorgaans last hebben van aanhoudend negatief affect en terugkerende negatieve gedachten (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008), de neiging hebben om hun aandacht langdurig te richten op (irrelevante) negatieve informatie en dit ten koste van een vlotte en adequate cognitieve prestatie. Dergelijke moeilijkheden met het inhiberen en het loskomen van irrelevante negatieve informatie kunnen leiden tot aanhoudende negatieve gedachten en gevoelens en kunnen zo de kans op het ontwikkelen of voortbestaan van depressieve symptomen significant verhogen (Joormann et al., 2007; Koster et al., 2011).

Ondanks toenemende interesse voor de invloed van emotionele stimuli op cognitieve controle bij depressieve volwassenen, is onderzoek bij adolescenten met depressieve symptomen momenteel schaars. Onderzoek in de laatstgenoemde leeftijdsgroep is echter zeer relevant aangezien de adolescentie gekenmerkt wordt door een disbalans tussen de emotionele en cognitieve ontwikkeling (Ernst, Pine, & Hardin, 2006). Meer specifiek wijst neuropsychologisch onderzoek bij adolescenten op een vroege ontwikkeling van ‘affectieve’ hersengebieden, zoals de amygdala, en een relatief late ontwikkeling van ‘cognitieve’ hersengebieden, zoals de prefrontale cortex. Dit onevenwicht stelt hun cognitieve controle vaardigheden in emotionele situaties op de proef en verhoogt hun kwetsbaarheid op het ontwikkelen van psychopathologie, en depressie in het bijzonder (Luciana, 2016; Luciana & Collins, 2012).
De hoofddoelstelling van dit doctoraatsproject was om de invloed van emotionele stimuli na te gaan op cognitieve controle processen bij adolescenten met depressieve symptomen. Hierbij lag de focus op drie kern EF componenten, namelijk informatie vasthouden en updaten in het werkgeheugen, inhibitie en shiften (Diamond, 2013; Miyake et al., 2000). In een eerste cross-sectionele vragenlijststudie bij 579 adolescenten tussen 10 en 16 jaar (Hoofdstuk 2) onderzochten we één van de centrale assumpties in dit project, namelijk dat het verband tussen cognitieve controle moeilijkheden en depressieve symptomen op zijn minst gedeeltelijk verklaard wordt door emotiedisregulatie of moeilijkheden met emotieregulatie. In de daaropvolgende hoofdstukken wilden we onderzoeken welke specifieke EF beperkingen aan de grondslag liggen van de emotiedisregulatie bij adolescenten met depressieve symptomen. Aangezien het vragenlijstendesign van Hoofdstuk 2 slechts een ‘ruwe’ meting van EF in het dagdagelijks leven oplevert, onderzochten we het effect van emotionele informatie op diverse EF componenten aan de hand van objectieve experimentele taken.

In Hoofdstuk 3 en Hoofdstuk 4 lag de focus op de invloed van emotionele stimuli op het werkgeheugen. Hiervoor werd in Hoofdstuk 3 gebruik gemaakt van een emotionele n-back taak waarin depressieve \( n = 27 \) en doorsnee adolescenten \( n = 49 \) een reeks gezichten te zien kregen en steeds moesten aangeven of de huidige stimulus hetzelfde was als de stimulus die \( n \)-trials daarvoor gepresenteerd werd. Vermits voorgaand onderzoek reeds heeft aangetoond dat het effect van emotionele informatie op cognitieve controle afhankelijk is van hun relevantie voor de taak (Kanske, 2012), bevatte onze n-back taak een emotie-relevante conditie, waarin men de aandacht moest richten op de emotionele uitdrukking op het gezicht, en een emotie-irrelevante conditie, waarin men de aandacht moest richten op het geslacht van het gezicht. In Hoofdstuk 4 wilden we de resultaten van Hoofdstuk 3 repliceren en aanvullen door een innovatieve oogbewegingstaak te gebruiken die een zoer ‘directe’ en precieze meting geeft van het werkgeheugen. In deze taak werden dysfore \( n = 25 \) en niet-dysfore adolescenten \( n = 40 \) gevraagd de locatie van kort gepresenteerde doelstimuli (i.e., gekleurde rechthoeken) te onthouden. Belangrijk is dat deze doelstimuli bedekten met emotionele gezichten die niet relevant waren voor de taak en dus genegeerd moesten worden.

Het doel van Hoofdstuk 5 en Hoofdstuk 6 was om de invloed van emotionele stimuli te meten op twee andere EF componenten, namelijk inhibitie en shifting. In Hoofdstuk 5 werd
een Negatieve Affectieve Priming taak gebruikt waarin dysfore (n = 21) en niet-dysfore adolescenten (n = 28) werden gevraagd om de valentie van een doelstimulus te evalueren en dit terwijl ze een simultaan gepresenteerde emotionele ‘afleider’ stimulus moesten inhiberen. Tot slot onderzochten we in Hoofdstuk 6 het vermogen om te shiften tussen emotionele en niet-emotionele informatie in het werkgeheugen aan de hand van een Internal Shifting taak. In deze taak kregen dysfore (n = 20) en niet-dysfore adolescenten (n = 34) een reeks gezichten te zien en moesten ze tellen en rapporteren hoeveel negatieve en neutrale gezichten (emotionele conditie) of hoeveel mannelijke en vrouwelijke gezichten (niet-emotionele conditie) ze zagen.

Een belangrijk verschil tussen de studies in Hoofdstuk 3 en 4 en de studies in Hoofdstuk 5 en 6 is dat de eerste twee studies volwassen gezichten includerden als emotionele stimuli, terwijl de experimentele taken in laatste twee studies kindergezichten bevatten.

**Overzicht van de belangrijkste bevindingen**

**Algemene Moeilijkheden met Cognitieve Controle**

Hoewel dit doctoraatsproject zich voornamelijk richtte op de invloed van emotionele informatie op cognitieve control processen, is het interessant om kort stil te staan bij de *algemene cognitieve controle vaardigheden* van adolescenten met depressieve symptomen. In tegenstelling tot de robuuste evidentie voor cognitieve controle moeilijkheden bij depressieve volwassenen, zijn onderzoeksresultaten bij jongere populaties immers veel minder eenduidig (voor een review zie Mueller, 2011). Zo vonden een aantal voorgaande studies duidelijke cognitieve controle beperkingen bij depressieve adolescenten (e.g., Han et al., 2016; Holler, Kavanaugh, & Cook, 2014; Sommerfeldt et al., 2016), terwijl andere studies er niet in slaagden om verschillen aan te tonen tussen depressieve en doorsnee groepen (e.g., Cataldo, Nobile, Lorusso, Battaglia, & Molteni, 2005; Constantinidou, Danos, Nelson, & Baker, 2011; Favre et al., 2009).

In het huidige proefschrift werd gedeeltelijke evidentie gevonden voor de relatie tussen cognitieve controle problemen en depressieve symptomen bij adolescenten. Zo toonden de resultaten van de vragenlijststudie (Hoofdstuk 2) een positief verband tussen EF beperkingen en depressieve symptomen in een steekproef bestaande uit gezonde, at-risk en klinisch ‘doorverwezen’ adolescenten. Bovendien werd deze relatie partieel gemedieerd een hoger gebruik van maladaptieve emotieregulatiestrategieën en een lager gebruik van adaptieve emotieregulatiestrategieën. Dit mediatie-effect bevestigt recente cognitieve modellen en
voorgaande studies die stellen dat problemen met cognitieve controle leiden tot de ontwikkeling van depressieve symptomen via emotiedisregulatie (Demeyer, De Lissnyder, Koster, & De Raedt, 2012; Joormann & Gotlib, 2010; Joormann & Quinn, 2014; Koster et al., 2011).

Verder toonden de resultaten van de emotionele n-back taak (Hoofdstuk 3) dat proportioneel meer depressieve adolescenten (13%) vergeleken met niet-depressieve adolescenten (1%) er niet in slaagden om een minimum accuraatheid van 60% te behalen op de oefenreeksen van de 2-back taak (i.e., huidige stimulus vergelijken met de stimulus die 2 trials daarvoor gepresenteerd werd). Deze resultaten wijzen op algemene moeilijkheden met het vasthouden en updaten van informatie in het werkgeheugen en zijn vergelijkbaar met de resultaten van een (beperkt) aantal voorgaande werkgeheugenstudies bij depressieve adolescenten (e.g., Bloch et al., 2013; Brooks, Iverson, Sherman, & Roberge, 2010; Matthews, Coghill, & Rhodes, 2008).

In tegenstelling tot de studies beschreven in Hoofdstuk 2 en Hoofdstuk 3, vonden de studies in Hoofdstuk 4 tot en met Hoofdstuk 6 geen verschillen wat betreft algemene cognitieve controle vaardigheden tussen dysfore en niet-dysfore adolescenten en werd met andere woorden geen evidentie gevonden voor de aanwezigheid van cognitieve controle moeilijkheden. De uiteenlopende resultaten wat betreft algemene cognitieve controle vaardigheden bij adolescenten met depressieve symptomen kunnen verklaard worden door het feit dat er doorheen de studies van dit project (1) verschillende metingen werden gebruikt om cognitieve controle in kaart te brengen (vragenlijsten vs. experimentele taken), (2) diverse EF componenten werden onderzocht (updaten in het werkgeheugen vs. informatie vasthouden in het werkgeheugen, inhibitie, shiften) en (3) verschillende steekproeven werden bestudeerd die varieerden wat betreft de ernst van hun depressieve symptomen (depressieve stoornis vs. dysforie).

De Invloed van Emotionele informatie op Cognitieve Controle Processen

De centrale doelstelling van de experimentele studies in dit doctoraat (Hoofdstuk 3-6) was om het effect van emotionele stimuli op drie kern EF componenten te onderzoeken bij adolescenten met depressieve symptomen. Opvallend is dat er twee patronen naar voor kwamen uit de resultaten van deze studies: één waaruit bleek dat de cognitieve controle prestatie van depressieve of dysfore adolescenten niet beïnvloed werd door emotionele stimuli
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(Hoofdstuk 3-4) en één waaruit bleek dat negatieve emotionele stimuli de aandacht trokken en een significant effect hadden op de cognitieve controle prestatie van dysfore adolescenten (Hoofdstuk 5-6).

**Intact vermogen tot cognitieve controle en afgevlakte emotionele reactiviteit.** De resultaten van de studies beschreven in Hoofdstuk 3 en Hoofdstuk 4 demonstreerden dat emotionele informatie geen effect had op het werkgeheugen van adolescenten met depressieve symptomen. Zo toonden de bevindingen van de emotionele n-back taak (Hoofdstuk 3) aan dat de werkgeheugenprestatie van depressieve adolescenten niet beïnvloed werd door relevante of irrelevante emotionele gezichten. De afwezigheid van effecten is opvallend gezien de prestatie van doorsnee adolescenten wel duidelijk beïnvloed werd door de aanwezigheid van *positieve* emotionele stimuli. Meer specifiek zorgden blije volwassengezichten voor snellere reactietijden in de emotie-relevante conditie en voor tragere reactietijden in de emotie-irrelevante conditie van de 2-back taak. Deze bevindingen zijn grotendeels in overeenstemming met theorie (Alloy & Abramson, 1988; Alloy, Albright, Abramson, & Dykman, 1990) en voorgaand onderzoek die suggereren dat depressieve individuen de neiging hebben om positieve en negatieve manier op een evenwichtige manier te verwerken en te onthouden (e.g., Gilboa, Roberts, & Gotlib, 1997; McCabe & Toman, 2000; Timbremont & Braet, 2004), terwijl gezonde individuen een *positiviteitsbias* of een voorkeur voor positieve informatie vertonen (Cromheeke & Mueller, 2015; Ladouceur et al., 2005).

In de oogbewegingsstudie in Hoofdstuk 4 vonden we eveneens dat irrelevante emotionele gezichten geen effect hadden op de werkgeheugenprestatie van dysforme adolescenten. Bij niet-dysforme adolescenten zagen we echter wel een duidelijk invloed van emotionele stimuli en vertraagden irrelevant boze volwassengezichten hun respons tijdens de werkgeheugentaak. De bevindingen bij doorsnee adolescenten passen binnen het “threat-relevance” model waarin wordt gesteld dat bedreigende informatie de aandacht trekt en een oriëntatiereflex ontlokt om zo het niveau van gevaar snel te kunnen inschatten (e.g., Kindt, van den Hout, de Jong, & Hoekzema, 2000; Lobue & DeLoache, 2008; Ohman & Mineka, 2001).

De bevindingen van Hoofdstuk 3 en Hoofdstuk 4 zijn conform met het ‘Emotion Context Insensitivity’ model van depressie waarin er wordt vooropgesteld dat depressieve individuen een afgevlakte reactiviteit vertonen ten opzichte van positieve en negatieve emotionele stimuli (Rottenberg & Gotfieb, 2004; Rottenberg, Gross, & Gotlib, 2005; zie
linkerkant van Figuur 2 in Hoofdstuk 7). Voortgaand op evolutionaire theorieën (Nesse, 2000), stelt dit model dat een depressieve stemming oorspronkelijk is ontstaan als een defensieve respons in tijden van stress en tegenspoed en op die manier ook aanleiding geeft tot een beperkte reactiviteit op nieuwe omgevingsstimuli. Deze afgevlakte (emotionele) reactiviteit wordt beschouwd als een belangrijke factor in het verstoord psychosociaal functioneren en de emotiedisregulatie waar depressieve individuen mee kampen.

**Bias naar negatieve informatie en emotie-specifieke shiftingsproblemen.** In tegenstelling tot de bovengenoemde resultaten, vonden Hoofdstuk 5 en Hoofdstuk 6 evidentie voor een bias naar negatieve informatie bij adolescenten met depressieve symptomen. Eerst en vooral wezen de resultaten van de Negatieve Affectieve Priming studie (Hoofdstuk 5) op een hogere interferentie en een hogere inhibitie van boze kindergezichten bij dysfore adolescenten in vergelijking met niet-dysfore adolescenten. Bovendien bleek er ook een positief verband te zijn tussen de mate van interferentie en de mate van inhibitie van negatieve emotionele stimuli. Dit betekent met andere woorden dat dysfore adolescenten meer verstoord werden door boze gezichten en deze bijgevolg ook meer gingen inhiberen. Verder toonde de studie met de Internal Shifting taak (Hoofdstuk 6) aan dat dysfore adolescenten specifieke shiftingsproblemen ervoeren bij het verwerken van negatieve emotionele informatie. Meer in het bijzonder demonstreerden de resultaten dat dysfore adolescenten moeilijkheden ondervonden en trager waren om hun aandacht weg te richten of los te koppelen van boze kindergezichten (i.e., intern shiften van boze naar neutrale stimuli).

Zowel de studie in Hoofdstuk 5 als de studie in Hoofdstuk 6 bevestigen een verstoorde cognitieve verwerking van negatieve informatie bij dysfore adolescenten. Meer specifiek kunnen we veronderstellen dat dysfore adolescenten beduidend meer verstoord worden door taak-irrelevante negatieve stimuli en deze stimuli daardoor ook meer inhiberen in vergelijking met doorsnee adolescenten (Hoofdstuk 5). Bovendien blijkt dat dysfore adolescenten ook meer moeilijkheden ervaren om hun aandacht los te koppelen van negatieve informatie wanneer de taak de actieve verwerking van emotionele informatie en flexibel shiften tussen mentale representaties vereist (Hoofdstuk 6). Deze resultaten liggen grotendeels in overeenstemming met recente cognitieve modellen (De Raedt & Koster, 2010; zie rechterkant van Figuur 2 in Hoofdstuk 7; Koster et al., 2011), die suggereren dat depressieve individuen een aandachtsbias vertonen naar schemacongruente negatieve informatie, zelfs wanneer deze
informatie irrelevant is voor de taak waarmee ze bezig zijn. Meer specifiek stellen deze modellen dat depressieve individuen hun aandacht moeilijk kunnen loskoppelen van negatieve (irrelevante) informatie waardoor ze deze informatie langdurig verwerken en minder goed in staat zijn om doelgericht en flexibel te handelen en hun emoties op een goede manier te reguleren.

**Naar een beter begrip van tegenstrijdige bevindingen.** De resultaten van de experimentele studies opgenomen in dit proefschrift zijn allerminst eenduidig wat betreft de invloed van emotionele informatie op cognitieve controle processen. Enerzijds toonden de resultaten van de eerste twee experimentele studies (Hoofdstuk 3-4) een afgevlakte emotionele reactiviteit tijdens het uitvoeren van werkgeheugentaak bij adolescenten met depressieve symptomen. Anderzijds bleek uit de bevindingen van de laatste twee studies dat dysfore adolescenten meer verstoord werden door negatieve irrelevante informatie en de neiging hadden om deze informatie meer te inhiberen (Hoofdstuk 5). Verder konden ze hun aandacht ook moeilijker shiften van negatieve naar meer neutrale informatie in vergelijking met doorsnee adolescenten (Hoofdstuk 6).

Het feit dat emotionele informatie enkel een invloed had in de laatste twee studies en niet in de eerste twee experimentele studies kan verklaard worden door het soort stimulus dat gebruikt werd in de diverse studies (kinder- vs. volwassen gezichten). We kunnen meer bepaald veronderstellen dat kindergezichten meer intens en relevant zijn vergeleken met volwassengezichten gezien de adolescentie een ontwikkelingsfase is waarin relaties met leeftijdgenoten meer centraal staan dan relaties met volwassenen en een significante invloed hebben op het emotioneel welzijn en de opbouw van het zelfbeeld (Laursen & Collins, 1994; Lerner & Galambos, 1998; Zimmer-Gembeck, Geiger, & Crick, 2005). Bovendien kunnen we ook verwachten dat boze kindergezichten depressogene schema’s van sociale afwijzing activeren en bijgevolg de aandacht trekken en een duidelijke invloed hebben op cognitieve controleprocessen (zie Figuur 3 – pad 2 in Hoofdstuk 7). Volwassengezichten kunnen daarentegen eerder als milde tot gemiddeld intense stimuli beschouwd worden die minder aandacht trekken en er niet in slagen om een (normatieve) emotionele reactie uit te lokken bij depressieve of dysfore adolescenten (zie Figuur 3 – pad 1 in Hoofdstuk 7).

Verder suggereren de resultaten van dit proefschrift dat emotionele informatie vooral de shiftingcomponent van cognitieve controle verstoort bij dysfore adolescenten. Zo zagen
we dat negatieve emotionele stimuli geen invloed hadden op het werkgeheugen (Hoofdstuk 3-4) en een hogere inhibitie respons ontloken bij adolescenten met depressieve symptomen (Hoofdstuk 5). Tijdens het uitvoeren van de Internal Shifting taak (Hoofdstuk 6), ervoeren dysfore adolescenten echter wel duidelijke problemen om hun aandacht flexibel te shiften tussen negatieve en neutrale informatie. Deze resultaten stemmen overeen met de “mental inflexibility” visie. In dit model wordt ervan uitgegaan dat de typische neiging van depressieve individuen om vast te blijven hangen in negatieve gedachten en gevoelens contra-intuïtief kan leiden tot een beter prestatie op taken waarin men dient vast te houden aan een doel ondanks de aanwezigheid van (irrelevante) emotionele stimuli. Wanneer een taak echter gericht is op het flexibel shiften tussen informatie, kan deze mentale inflexibiliteit hun vermogen om aandacht te verplaatsen tussen diverse stimuli of mentale representaties sterk verstoren (Altamirano, Miyake, & Whitmer, 2010; Goschke, 2000; Koval, Kuppens, Allen, & Sheeber, 2012; zie Figuur 3 - kader met stippellijn).

Klinische Implicaties

De resultaten van de studies in dit proefschrift kunnen bijdragen aan een beter begrip van hoe emotionele en cognitieve controle processen bijdragen aan depressieve symptomen bij adolescenten. Hoewel het niet de hoofdfocus was van het huidige doctoraatsproject, toonden onze bevindingen dat de algemene cognitieve controle vaardigheden relatief intact zijn bij depressieve adolescenten. Zo kwamen beperkingen enkel naar voor op vlak van alledaagse gedragingen gerelateerd aan EF (zoals gemeten met de BRIEF vragenlijst; Hoofdstuk 2) en complexe werkgeheugenprestaties (zoals gemeten met de n-back taak; Hoofdstuk 3) en niet op vlak van informatie vasthouden in het werkgeheugen, inhibitie of shifting (Hoofdstuk 4-6). Een interessante invalshoek voor toekomstig onderzoek is om participanten te vergelijken die verschillen wat betreft leeftijd en ernst van depressieve klachten en te exploreren vanaf wanneer de cognitieve controle capaciteit van depressieve individuen duidelijk uitgeput geraakt en het organiseren een EF training voordelig zou kunnen zijn.

Wat betreft de invloed van emotionele informatie op cognitieve controle zijn onze resultaten behoorlijk uiteenlopend, maar wijzen ze allemaal op een vorm van cognitieve of mentale rigiditeit bij depressieve of dysfore adolescenten. Bijgevolg is het belangrijk dat toekomstig onderzoek de effectiviteit van een ‘affectieve’ cognitieve controle training, gericht op het verhogen van flexibiliteit ten aanzien van emotionele informatie, onderzocht bij
adolescenten met verhoogde depressieve symptomen. Interessant in dit opzicht is dat we op basis van een review van Wadlinger and Isaacowitz (2011) kunnen besluiten dat aandachtsprocessen, zoals het loskomen van negatieve stimuli of het heroriënteren naar positieve stimuli, getraind kunnen worden via uitvoerige trainingsprogramma’s en dat dergelijke aandachtstrainingen ook ruimere effecten hebben op de emotieregulatievaardigheden van participanten. Helaas zijn de studies opgenomen in deze review allemaal gericht op volwassenen en kunnen de resultaten dus niet zomaar gegeneraliseerd worden naar jongere populaties.

Aangezien de invloed van emotionele stimuli op cognitieve controle processen niet eenduidig is en de effectiviteit van ‘affectieve’ cognitieve controle trainingen nog niet aangetoond is bij depressieve adolescenten, lijkt de meest aangewezen stap voor toekomstige preventie- en interventieprogramma’s om te focussen op het aanleren van “compensatiestrategieën”. Op basis van de vragenlijststudie besproken in Hoofdstuk 2 kunnen we veronderstellen dat een adequate emotieregulatie een vaardigheid is die mogelijk kan compenseren voor de nefaste effecten van disfunctionele cognitieve controle processen bij adolescenten met depressieve symptomen. Meer specifiek kunnen we verwachten dat programma’s gericht op het aanleren van adaptieve strategieën (vb., cognitieve herbeoordeling, probleemoplossing) en het beperken van maladaptieve strategieën (vb. rumineren, onderdrukken) de negatieve effecten van disfunctionele cognitieve processen op depressieve symptomen (op zijn minst gedeeltelijk) kunnen opvangen.

Conclusie

Doorheen dit proefschrift gingen we de invloed van emotionele stimuli op cognitieve controle processen na bij adolescenten met depressieve symptomen. De resultaten van een eerste vragenlijststudie toonden aan dat emotieregulatie een belangrijke onderliggende rol speelt in het verband tussen cognitieve controle moeilijkheden en depressieve symptomen. De daaropvolgende experimentele studies focusten op specifieke EF componenten en hun resultaten wezen in verschillende richtingen. Zo toonden de werkgeheugenstudies een afgevlakte emotionele reactiviteit bij depressieve/dysfore adolescenten, terwijl uit de laatste twee experimentele studies bleek dat dysfore adolescenten een verhoogde inhibitierespons toonden en shiftingsmoeilijkheden ervoeren in de context van negatieve emotionele stimuli. Op basis van deze wisselende resultaten kunnen we concluderen dat er nood is aan toekomstig
onderzoek dat enerzijds meerdere experimentele taken opneemt om één specifieke EF component te meten en anderzijds ook systematisch een aantal taak- en stimuluseigenschappen die een invloed zouden kunnen hebben op de resultaten manipuleert en vergelijkt (vb. volwassen vs. kindgezichten; taakrelevante vs. taakirrelevante emotionele stimuli). Verder is er ook nood aan longitudinaal onderzoek dat nagaat of cognitieve en emotionele processen een onderliggende rol spelen in de ontwikkeling en het voortbestaan van depressieve symptomen en niet enkel een symptoom zijn van een depressieve stemming. Op klinisch vlak bevestigen de resultaten dat het aanleren van compensatiestrategieën zoals adaptieve emotieregulatie een veelbelovende invalshoek is voor toekomstige preventie- en vroege interventieprogramma’s.
Referenties


Luciana, M. (2016). Executive Function in Adolescence: A Commentary on Regulatory Control and Depression in Adolescents: Findings From Neuroimaging and
Neuropsychological Research. *Journal of Clinical Child and Adolescent Psychology, 45*(1), 84-89. doi: 10.1080/15374416.2015.1123638


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- [x] other files. Specify: Script in R (R File) for transformations on raw data

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- [x] individual PC
- [x] research group file server
- [ ] other: ...

* Who has direct access to these other files (i.e., without intervention of another person)?
- [x] main researcher
- [ ] responsible ZAP
- [ ] all members of the research group
- [ ] all members of UGent
- [x] other (specify): IT worker Steven Vandenhole

4. Reproduction

* Have the results been reproduced independently?: [ ] YES / [x] NO

* If yes, by whom (add if multiple):
  - name:
  - address:
  - affiliation:
  - e-mail:
Data Storage Fact Sheet

Name/identifier study: Chapter 5 PhD Laura Wante
Author: Laura Wante
Date: 14/07/2017

1. Contact details

1a. Main researcher

- name: Laura Wante
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1b. Responsible Staff Member (ZAP)

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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.

2. Information about the datasets to which this sheet applies

==================================================================================
* Reference of the publication in which the datasets are reported:

- Doctoral thesis Laura Wante (Chapter 5)

* Which datasets in that publication does this sheet apply to?: The sheet applies to all the data used in the publication.

3. Information about the files that have been stored

=====================================================

3a. Raw data

======================================================================

* Have the raw data been stored by the main researcher? [x] YES / [ ] NO

If NO, please justify:

* On which platform are the raw data stored?
  - [x] researcher PC
  - [x] research group file server
  - [ ] other (specify): ...

* Who has direct access to the raw data (i.e., without intervention of another person)?
  - [x] main researcher: behavioural data and questionnaires
  - [ ] responsible ZAP
  - [ ] all members of the research group
  - [ ] all members of UGent
- [x] other (specify): IT worker Steven Vandenhole

3b. Other files

* Which other files have been stored?
- [ ] file(s) describing the transition from raw data to reported results. Specify: see methodology in Chapter 5
- [x] file(s) containing processed data. Specify: SPSS (.sav) and excel files (.xlsx)
- [x] file(s) containing analyses. Specify: SPSS outputs (.spv)
- [x] files(s) containing information about informed consent (blank copy of the informed consent form)
- [x] a file specifying legal and ethical provisions: The documents that were submitted to the Ethical Commission are on my PC and I have a paper letter with the approval of the Ethical Commission.
- [ ] file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
- [ ] other files. Specify:

* On which platform are these other files stored?
- [x] individual PC
- [x] research group file server
- [ ] other: ...

* Who has direct access to these other files (i.e., without intervention of another person)?
- [x] main researcher
- [ ] responsible ZAP
- [ ] all members of the research group
- [ ] all members of UGent
- [x] other (specify): IT worker Steven Vandenhole

4. Reproduction

* Have the results been reproduced independently?: [ ] YES / [x] NO

* If yes, by whom (add if multiple):
  - name:
  - address:
  - affiliation:
  - e-mail:
Data Storage Fact Sheet

Name/identifier study: Chapter 6 PhD Laura Wante
Author: Laura Wante
Date: 14/07/2016

1. Contact details

1a. Main researcher

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- address: Henri Dunantlaan 2, 9000 Gent
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1b. Responsible Staff Member (ZAP)

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2. Information about the datasets to which this sheet applies

* Reference of the publication in which the datasets are reported:
- Doctoral thesis Laura Wante (Chapter 6)
DATA STORAGE FACT SHEETS


* Which datasets in that publication does this sheet apply to?: The sheet applies to all the data used in the publication.

3. Information about the files that have been stored

3a. Raw data

* Have the raw data been stored by the main researcher? [x] YES / [ ] NO
If NO, please justify:

* On which platform are the raw data stored?
  - [x] researcher PC
  - [x] research group file server
  - [ ] other (specify): ...

* Who has direct access to the raw data (i.e., without intervention of another person)?
  - [x] main researcher
  - [ ] responsible ZAP
  - [ ] all members of the research group
  - [ ] all members of UGent
  - [x] other (specify): IT worker Steven Vandenhole
3b. Other files

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- [x] file(s) describing the transition from raw data to reported results. Specify: see methodology in Chapter 6
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- [ ] other files. Specify:

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