Running head: DEPRESSION AND COGNITIVE CONTROL

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Internal cognitive control in clinical depression: General but no emotion-specific impairments

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Abstract
Prior research has suggested that depression is characterized by impaired cognitive control. The present study sought to investigate internal cognitive control impairments related to emotional information and task settings in clinical depression (MDD, major depressive disorder). Internal cognitive control was operationalized as switching between internally held mental representations that required continuous updating in working memory and measured with the Internal Shift Task (IST). The results showed that MDD individuals were characterized by a general switching impairment. This switching impairment was neither influenced by the task-relevance of emotional information, nor influenced by the valence of the faces within the emotion condition. The impairment in cognitive control reflected in general switching impairments was related to rumination, a specific cognitive symptom and important risk factor of depression. The results of this study offer new insights into the relationship between depression and impaired cognitive control with potential clinical implications, informing treatment and prevention programmes.
Keywords: switching, working memory, internal attention, rumination

1. Introduction

Major depressive disorder (MDD) is one of the most common and debilitating mental disorders (Kessler, 2003). Although current pharmacological and psychological interventions are quite effective in reducing depressive symptoms at the short term, relapse rates remain very high (Kessler et al., 2005). Given the high prevalence and recurrence rates of depression, an important research challenge is to identify the underlying vulnerability factors for depression. In the past, theoretical models of cognitive vulnerability for depression and related empirical studies have focused primarily on examining cognitive products or the negative content of depressive cognition. Recently, theoretical models highlight the importance of underlying *cognitive processes* that might be related to negative cognition and the core affective symptoms of depression, such as sustained negative affect and impaired emotion regulation (Joormann and D‟Avanzato, 2010). Toward this goal, a wealth of research has investigated the relationship between depression and information processing impairments as cognitive vulnerability factors (Clark et al., 1999; Alloy et al., 2000). An enhanced theoretical understanding of information processing impairments in depression may help to improve current treatments by targeting the crucial cognitive risk factors.

It has been proposed that impairments in the cognitive control functions of working memory might operate across the various cognitive biases, such as mood-congruent interpretation biases, memory biases, and attentional biases, acting as an important mechanism underlying depression (Joormann, 2005). Cognitive control refers to the ability to override pre-potent responses and to inhibit the processing of irrelevant or previous relevant information. These abilities are related to the functioning of executive control processes, such as inhibition, switching, and updating in working memory (Miyake et al., 2000). Recently, a wealth of research has begun to investigate whether depression is related to cognitive control impairments using a variety of cognitive-experimental tasks.

There is some neuropsychological evidence suggesting that depression is associated with general impairments in cognitive control. Research has indicated that depressed persons make more perseverative errors on the Wisconsin Card Sorting Task (WCST), a widely used measure of cognitive control and flexibility, suggesting switching impairments when processing non-emotional information (Merriam et al., 1999; Grant et al., 2001; Harvey et al., 2004). Research using the *n*-back task (Harvey et al., 2004), Go/Nogo (Kaiser et al., 2003), and the antisaccade task (Sweeney et al., 1998), has also provided some evidence for impaired inhibition in working memory in depression. However, many studies have provided only limited support for the idea that depression is related to cognitive control impairments when processing non-emotional information (Joormann et al., 2007), with marked impairments only being present in severe depression (Kaiser et al., 2003).

Provided the mixed findings on general cognitive control impairments in depression, it has been argued that cognitive control is particularly hampered in the context of processing negative, mood-congruent information (Joormann et al., 2007). There is a wealth of research examining differences in cognitive control using tasks where negative and neutral information is presented. Such research has revealed that depression is associated with difficulties to inhibit processing of task-irrelevant negative material (Joormann, 2004; Goeleven et al., 2006), as well as problematic trial-by-trial updating of negative information in working memory (Joormann and Gotlib, 2008; Levens and Gotlib, 2010). Remarkably, only little research has examined whether the task-relevance of the emotional information is associated with the magnitude of cognitive control impairments. Much research has examined whether task-irrelevant emotional information interferes with cognitive control (for instance in the emotional stroop task). However, in relation to depression, individuals often have positive beliefs about focusing on emotions in the form of rumination (see Below; Papageorgiou and Wells, 2003). Therefore, cognitive impairments may be larger when individuals are required to focus on the emotional features of stimuli, compared with the situation were a non-emotional feature is task relevant. (Joormann and Gotlib, 2008; Joormann et al., 2007).

Recently, impaired cognitive control has been investigated in relation to specific cognitive vulnerability factors for depression, such as a ruminative thinking style (Koster et al., 2011). Rumination is defined as "behaviours and thoughts that focus one‟s attention on one‟s depressive symptoms and on the implications of those symptoms" (Nolen-Hoeksema, 1991, p. 569). Two distinct subtypes of rumination are distinguished (Treynor et al., 2003). The first, reflective pondering, is considered a more adaptive form of rumination and reflects the degree to which individuals engage in cognitive problem solving to improve their mood. The second, depressive brooding, is considered a more maladaptive form of rumination and reflects the degree to which individuals passively focus on symptoms of distress and the meaning of those symptoms (Nolen-Hoeksema et al., 2008). The brooding component is proposed to be most closely related to depression risk (Treynor et al., 2003). Research indicates that rumination is related to impaired cognitive control when processing non-emotional information (Davis and Nolen-Hoeksema, 2000; Whitmer and Banich, 2007; De Lissnyder et al., 2011) as well as emotional information (Joormann, 2006; Lau et al., 2007; Joormann and Gotlib, 2008; De Lissnyder et al., 2010; Joormann et al., 2010; De Lissnyder et al., in press). Previous research showed that particularly depressive brooding was related to the cognitive control impairments.

Research into cognitive control has historically employed tasks which measure cognitive control for externally presented stimuli. Given that the ability to control *internal* negative information (i.e., the ability to intentionally switching attentional focus from unpleasant/negative thoughts to more pleasant/positive thoughts) could specifically be an important process underlying vulnerability for depression and rumination, it would be interesting to investigate cognitive control ability for internal mental representations held in working memory. An interesting task that allows to examine whether depression is related to internal cognitive control impairments and whether the impairments are related to the task relevance of the emotional information is the Internal Shift Task (IST; De Lissnyder et al., in press). This task is based on work by Garavan (1999) and Gehring and colleagues (Gehring et al., 2003), who developed a paradigm to examine cognitive control for internal mental representations held in working memory. Recently, Chambers et al. (2008) developed an affective version of this paradigm using words as stimuli. We further modified this task to include emotional facial expressions and refer to this task as the Internal Shift Task (IST). Importantly, cognitive control consists of a number of different sub-processes (Miyake et al., 2000), but recent evidence indicates that inhibition and switching are interrelated (Koch et al., 2010). Therefore, the IST is framed in functional terms of task demands, namely updating of and mainly switching between mental representations held in working memory.

In the IST, individuals are required to perform a mental count based on emotional features of a face (i.e., count the number of negative and neutral faces) in one block (referred to as emotion condition) or on non-emotional features of a face (i.e., count the number of male and female faces) in another block (referred to as gender condition). Research indicates that the IST is a reliable and valid measure of internal cognitive control (De Lissnyder et al., submitted). In addition, the task settings of the IST are designed to demand the execution of cognitive control in a self-directed unconstrained manner instead of being cued on a trial-of-trial basis. It has been argued that depression related impairments would be most operative under such conditions (Hertel, 2004). Interestingly, the IST allows to examine impaired internal switching in relation to specific task settings (emotion versus gender condition), general switching impairments (across both emotion and gender conditions), and valence-specific impairments (within the emotion condition). To investigate switching impairments, switch costs are calculated. The examination of switch costs is crucial because they index the efficiency of switching between mental representations held in working memory. In the switching literature, the RT switch cost is typically referred to as the difference in RT between switch and no-switch (or repeat) trials (Monsell, 1996).

In our previous studies with the IST (De Lissnyder et al., in press; De Lissnyder et al., submitted), we have investigated the ability to switch between internal mental representations held in working

memory in dysphoric undergraduate samples. Specific advantages of conducting studies with dysphoric samples are (1) the exclusion of medication use, which can influence cognitive functioning (Amado-Boccara et al., 1995); and (2) the relatively moderate correlations between different symptoms of depression and rumination, which allows to study specific correlations between cognitive control, depressive symptoms, and rumination. In these studies, we found that individuals with high rumination scores had more difficulty in switching in the emotion condition, and mainly when switching attention away from negative faces. In these studies, internal switching impairments were related to rumination scores, but not to subclinical depression levels. The rumination component that was most predictive of the internal switching impairments was depressive brooding, whereas no effects with reflective pondering were observed.

At present it is unclear whether these results generalize to a clinical sample. As cognitive control has to be exercised over internally held mental representations in working memory during IST performance, we hypothesized that switching impairments are found in relation to clinical depression and in particular to ruminative tendencies in this population (depressive brooding). In sum, to examine cognitive control impairments in clinical depression we used the IST to test whether depression is associated with:

- Impairments related to the task relevance of emotional information (reflected by differential switch costs between the emotion and gender condition);
- General cognitive control impairments (reflected by higher general switch costs);
- Impairments related to the valence of information in the emotion condition (reflected by differential switch costs between negative and neutral material in the emotion condition).

2. Method

2.1. Participants

Participants were 40 adults (23 females, 17 males) ranging in age from 23 to 59 years (M = 42.45 years, SD = 12.35). Two groups of participants volunteered to take part in this study: Twenty participants diagnosed with major depressive disorder (MDD) and 20 non/never-depressed control participants (NDC). The groups did not differ in age, $t(38) = 1.427$, p=.16, gender, $\chi_2(1, N=40) = .102$, p=.749, or education, $\chi_2(1, N = 40) = 5.867$, p=.118. Further group characteristics are shown in Table 1.

(Table 1 about here)

2.1.1. Selection criteria

Participants included in the MDD group were recruited at an inpatient psychiatric clinic (RGC) in Terneuzen (the Netherlands) and at the university hospital of Ghent (Belgium). The NDC participants were recruited from the community. In order to obtain an eligible diagnosis of major depression, all participants were screened using three different clinical measures. First, all participants were interviewed using the Dutch version of the Mini International Neuropsychiatric Interview (MINI; Pinninti et al., 2003). This interview schedule assesses current and lifetime psychiatric disorders based on DSM-IV-TR criteria (Sheehan et al., 1998). Secondly, participants were interviewed using the 17-item version of the Hamilton Rating Scale for Depression (HRSD), a well-validated interview to asses severity of depression (Hamilton, 1967). Only patients scoring above a cut-off score of 19, indicating severe depression, were further included in the MDD group. Finally, participants completed the Beck Depression Inventory-II-NL (BDI-II-NL; (Beck et al., 1996; Van der Does, 2002), a reliable and valid self-report measure of intensity of depression (Beck et al., 1988). Based on cut-off score guidelines (Beck et al., 1996), only participants scoring above 19 were included in the MDD group. The NDC group had no diagnosis of a current or past Axis I disorder on the MINI and showed no depressive symptoms on the HRSD and BDI-II-NL.

2.2. Materials

2.2.1. Additional self-report questionnaires

2.2.1.1. Rumination

The Ruminative Response Scale (RRS-NL) was used to measure rumination (Nolen-Hoeksema and Morrow, 1991; Raes and Hermans, 2003). The RRS-NL is a 26-item self-report measure and consists of items that describe responses to a depressed mood that are focused on the self, symptoms, or consequences of depressed mood. Participants are requested to indicate how often they engage in these responses using a four-point Likert scale ranging from 1 (almost never) to 4 (almost always). Total rumination scores range from 26 to 104. A factor analysis of the RRS has identified two separate subscales that are differentially related to depressive symptoms, reflective pondering and depressive brooding. The RRS is a reliable and valid measure of rumination with good psychometric properties (Treynor et al., 2003).

2.2.1.2. Anxiety

Participants of both groups also completed the Dutch trait version of the State-Trait Anxiety Inventory (STAI-T; Spielberger et al., 1983; Van der Ploeg et al., 2000), a self-report questionnaire measuring the tendency to respond with anxiety to perceived threats in the environment. The STAI-T is a reliable and valid measure with good psychometric properties (Van der Ploeg et al., 2000).

2.2.2. Internal Switch Task (IST)

The task was programmed using E-prime 2.0 software package and ran on a Windows XP computer with a 75 Hz, 19-inch colour monitor.

The stimuli were faces taken from the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998). All faces were adjusted to exclude interference of background stimuli (hair) and were adjusted to the same size (326 x 326 pixels). Based on intensity (1=not at all - 9=completely) and arousal (1=calm - 9=aroused) ratings a total of 24 neutral (Intensity: M=5.15, SD=0.37; Arousal: M=2.48, SD=0.23) and 24 angry (Intensity: M=6.36, SD=0.71; Arousal: M=3.87, SD=0.58) faces

were selected from a validation study of the KDEF picture set (Goeleven et al., 2008). Faces were chosen as stimuli material instead of words as depression seems to be characterized by disruptions in the interpersonal domain (Gotlib and Hammen, 2002). In particular, angry faces were selected as they have a direct relevance to depression, which is characterized by fear of social rejection (Barnett and Gotlib, 1988).

In the IST, faces are presented at the centre of the computer screen one at a time. All participants were asked to complete two conditions, an *emotional task irrelevant* condition (hereafter referred to as gender condition) and an *emotional task relevant* one (hereafter referred to as emotion condition). The two conditions (emotion and gender) were completed sequentially and the order in which the conditions were completed was counterbalanced across subjects. In the gender condition, participants had to focus on the „gender‟ dimension of the face (the faces had to be categorized as male or female), in the emotion condition, they had to focus on the „emotion‟ dimension of the face (the faces had to be categorized as neutral or angry). There were 12 blocks of trials (or faces) for both conditions with random 10 to 14 trials (or faces) within each block. The participant‟s task was to keep a silent mental count of the number of faces in each category, presented within a block of trials (e.g., participants had to update counters for male and female faces in the gender condition; participants had to update counters for neutral and angry faces in the emotion condition). When a face was presented, participants were asked to press the spacebar as fast as possible (*reaction time measure*) to indicate that they had updated both internal counters. The next face appeared on the screen after a 200ms inter-trial interval. Participants had to report the number of faces of both categories (*accuracy measure*), using the number path of the keyboard, at the end of each block in a fixed order to encourage a consistent counting strategy (e.g., in the emotion condition they had to report their counts first for the neutral and then for the angry faces, in the gender condition the order was male-female).

The faces and order of trials was determined using a random selection with replacement procedure which avoids predictable sequences for the participants. Due to the sequence of the faces, there were multiple switch and no switch trials in each block of items. Switch costs were calculated as the difference in reaction time between switch and non-switch trials within the blocks and served as the main dependent variable in the analyses. A trial is regarded as a switch trial if a target trial (*n*) has to be updated on a different category as its preceding trial (*n-1*) (i.e., in the emotion condition angry-neutral and neutral-angry). A trial is regarded as a no-switch trial if a target trial (*n*) has to be updated on the same category as its preceding trial (*n-1*) (i.e., in the emotion condition angry-angry and neutral-neutral). In addition, due to the task design, valence-specific emotional switching effects could be investigated (i.e., comparing the switches angry-neutral versus neutral-angry in the emotion condition). The practice phase consisted of 3 blocks of items and the experiment phase of 12 blocks of items in each condition. An example of a block of items and stimulus display is presented in Figure 1.

(Figure 1 about here)

2.3. Procedure

At the beginning of the experiment, written informed consent of all participants was obtained. Thereafter, participants performed the IST. Participants were asked to perform the task as quickly and accurately as possible. They practiced the IST and then completed the experimental phase consisting of 12 blocks of items in both emotion and gender conditions, with a short break in between. Participants completed the clinical interviews and the self-report questionnaires at the end of the session.

2.4. Data-analytic plan

To investigate whether depression is associated with cognitive control impairments related to the task relevance of emotional information, a mixed ANOVA with Condition (emotion, gender) and Switch Type (switch, no-switch) as within subject factors and Group (MDD, NDC) as between subject factor was carried out on response latencies (RT). To further analyze our data, switch costs were calculated. To investigate whether depression is associated with general cognitive control impairments, we examined switch cost across both emotion and gender condition. To

investigate whether depression is associated with cognitive control impairments related to the valence of information within the emotion condition, four different sequences of faces were compared, referred to as valence face *n*-1 followed by valence face *n*. Switch sequences could be angry-neutral or neutral-angry trials and no-switch sequences were angry-angry or neutral-neutral trials.

3. Results

For the analyses of reaction times, median scores were used to reduce any influence of outliers in the within-subject data. All blocks of items, correct and incorrect, were included in the data-analyses (cf. De Lissnder et al., in press). A block of items was considered as correct only if both reported numbers of the faces in each category were accurate. When taking this criterion into account, average accuracy was 83%. There were no significant differences in error rate between conditions or between groups, $F<2$. There was also no condition x group interaction on error rates, $F<2$.

The mixed ANOVA with Condition (emotion, gender) and Switch Type (switch, no switch) as within-subject factors and Group (MDD, NDC) as between-subject factor revealed a significant main effect of Group, $F(1, 38) = 16.74$, $p<.001$, with reaction times in the depressed group (M = 1510ms, SD = 260ms) being slower than reaction times in the control group (M = 1208ms, SD = 212ms). Analyses also revealed a main effect of Condition, $F(1, 38) = 9.58$, $p<.01$, with reaction times in the emotion condition (M = 1426ms, SD = 333ms) being slower than reaction times in the gender condition (M = 1300ms, SD = 282ms), and a main effect of Switch Type, $F(1, 38) = 126.90$, $p<.001$, with reaction times on switch trials (M = 1535ms, SD = 342ms) being slower than reaction times on no-switch trials (M = 1180ms, SD = 249ms). There was no significant two-way interaction between group and condition, $F(1, 38) = 2.13$, $p>.1$. Moreover, no significant three-way-interaction effect was observed, $F<1$.

Interestingly, analyses revealed a significant Switch Type x Group interaction, $F(1, 38) = 4.24$, $p<.05$. To further corroborate this interaction effect we examined general switch costs across both emotion and gender condition. Between group comparisons revealed that the general switch cost was significant higher in the depressed group (M = 423ms, SD = 251ms) compared to the control group (M = 287ms, SD = 123ms), $t(38) = 2.17$, $p<.05$ (Cohen‟s d = .69). This effect is depicted in Figure 2.

(Figure 2 about here)

To explore valence-specific cognitive control impairments in the emotion condition, performance on switches (angry-neutral, neutral-angry) and no-switches (angry-angry, neutral-neutral) was investigated. A mixed ANOVA on median reaction times with Valence Face *n*-1 (neutral, angry) and Valence Face *n* (neutral, angry) as within-subject factors and Group (MDD, NDC) as between-subject factor revealed a main effect of Valence Face *n-1*, $F(1, 38) = 5.65$, $p<.05$, and Valence Face *n*, $F(1, 38) = 4.79$, $p<.05$, and a Valence Face *n*-1 x Valence Face *n* interaction effect, $F(1, 38) = 126.33$, $p<.001$. The effects can be subsumed under a marginally significant three-way interaction effect, $F(1, 38) = 4.00$, $p=.053$. To further corroborate the three-way interaction we performed separate ANOVAs for no-switch and switch trials, where the a-priori prediction is that performance in the depressed group is hampered on the angry-neutral switch trials. However, we failed to find the predicted two-way interaction for analyses of the switch (angry-neutral versus neutral-angry) as well as the no-switch trials (angry-angry versus neutral-neutral), Fs < 1. The results are depicted in Figure 3.

Additional correlational analyses are shown in Table 2 and revealed significant correlations between general switching impairment and the BDI-II-NL and total RRS scores.

(Table 2 about here)

4. Discussion

The present study sought to investigate cognitive control impairments related to emotional information and task settings in clinical depression using the Internal Shift Task (IST; De Lissnyder et al., in press). In the presented study cognitive control was operationalized as switching between internally held mental representations in working memory. The results showed that MDD individuals were characterized by a general switching impairment. This switching impairment was neither influenced by the task relevance of emotional information, nor influenced by the valence of the faces within the emotion condition. These results are discussed in turn below.

The finding of a general impairment in cognitive control in clinical depression fits with recent theoretical models and previous studies in depression. That is, there already are a number of studies demonstrating that various aspects of cognitive control are impaired in (severely) depressed individuals (Merriam et al., 1999; Kaiser et al., 2003; Harvey et al., 2004; Meiran et al., 2010). Interestingly, in previous studies using the IST in dysphoric undergraduate populations we failed to observe correlations between symptoms of depression and cognitive control impairments whereas specific relations were observed with rumination (De Lissnyder et al., in press; De Lissnyder et al., submitted). Thus, the present study suggests that impaired cognitive control indeed is a feature of severe levels of clinical depression. One important advantage of the IST is that it allows to examine cognitive control that is exercised over internally held mental representations in working memory, which seems to be of particular importance in depressed individuals, as they are characterized by persistent and negative thoughts and images. Despite emotion regulation attempts to remove such thoughts from consciousness, depressed individuals have marked difficulties to succeed at this process (Wenzlaff and Wegner, 2000).

As the present study set out to examine the effects of the task relevance of emotional information and the influence of emotional material on cognitive control, the absence of emotion specific effects deserves some consideration. First, it is interesting that the task relevance of emotional information did not influence the switch costs in depressed versus non-depressed individuals. This finding can be interpreted as evidence against the notion that depressed individuals have particular difficulties in updating *emotional information* (Joormann and Gotlib, 2008). Yet, it is possible that the task irrelevant emotional information presented during the gender condition did attract more attention in depressed individuals, obscuring differences between both conditions. Indeed, in the gender condition, the faces were also angry versus neutral. This idea is in line with the proposal of Siegle et al. (2002) who argued that there is more interference of task-irrelevant affective information in depressed versus non-depressed individuals. However, if the task-irrelevant information would have captured more attention in the depressed individuals one would expect slower reaction times in the gender condition for these individuals which was not the case here. Second, the absence of trial-by-trial effects of emotional valence on cognitive control in the emotion condition is intriguing. This finding is different from our previous research in subclinical depression where such a valence-specific effect was found in relation to individual differences in rumination (De Lissnyder et al., submitted). The absence of this finding may have several reasons. It could be that the distinction between negative and neutral information is less pronounced for depressed individuals who have been found to interpret ambiguous faces as more negative than non-depressed individuals (Joormann and Gotlib, 2006). Alternatively, it is possible that the presence of negative emotional information causes a sustained switching impairment instead of modulating cognitive control on a trial-by-trial basis. An important consideration here is that negative emotional information was presented in all conditions and it would be important to examine whether similar effects are observed under conditions where negative information is fully absent.

In this study, depressive brooding was not the best predictor of the cognitive control impairments, in contrast with our studies in dysphoric samples (De Lissnyder et al., in press; De Lissnyder et al., submitted). Self-reported rumination scores were related to impairments in cognitive control,

but there was no significant or differential relationship with brooding or reflection. The absence of a particular relation with brooding in this depressed sample can be linked to the findings of a recent study (Whitmer and Gotlib, 2011) indicating that the distinction between brooding and reflection is blurred in currently depressed individuals. Using factor analyses, they found support for the distinction between reflection and brooding in never-depressed and formerly depressed individuals, but they did not obtain the predicted two-factor structure in a currently depressed sample. These recent findings (Whitmer and Gotlib, 2011) may explain why we found a relation between impaired cognitive control and brooding in our dysphoric samples, but no differential relation with reflection or brooding in our depressed sample.

There are several interesting theoretical as well as clinical implications of the findings of this study. First, our results show that general cognitive impairments are observed in more severe levels of depression, but not in subclinical depression. A specific relation between cognitive control of emotional, and mainly negative, information and rumination was observed in subclinical depression (De Lissnyder et al., press; De Lissnyder et al., submitted), whereas clinical levels of depression are associated with overall, but no distinct emotion-specific or valence-specific impairments in cognitive control. These different patterns of findings across subclinical and clinical depression suggests that the emotion-specificity and valence-specificity of the cognitive control impairments may differ in initial vulnerability to depression and rumination compared with the cognitive correlates of moderate and more severe clinical depression. This observation warrants more fine-grained research into information processing in relation to the transition from subclinical to clinical levels of depression.

An improved understanding of cognitive vulnerability factors for depression, such as impaired cognitive control, can have important clinical implications, informing prevention and treatment programs for depression. Recently, studies have started to show that cognitive control can be improved with practice. A study of Siegle et al. (2007) has indicated that training cognitive control led to a significant reduction in depressive symptoms and rumination. This suggests that training cognitive control may be an additional treatment component of depression that may improve the ability to regulate emotions in response to negative events. If cognitive processes are causally linked to the affective problems, modifying these underlying cognitive processes holds promise to improve depressive affect (Koster et al., 2009).

Some limitations of this study should be noted. Most of the patients were on antidepressant medication and it is well known that alterations in serotonin levels can influence emotional information processing (Merens et al., 2007). As this might have influenced the effects in this study, it would be important to repeat this study in a non-medicated depressed sample. In addition, it would be interesting to repeat this study in a sample of outpatients, characterized by lower levels of depression to examine further the effect of depression severity. A second limitation of this study concerns the high correlations found between depressive symptoms (BDI-II-NL) and trait anxiety scores (STAI-T), r=.871, p<.001, and a co-morbid diagnosis of a variety of anxiety disorders in some of the MDD participants. Most previous studies have also reported high correlations between depression and anxiety and this co-morbidity occurs frequently in clinical practice (Mineka et al., 1998). However, the general impairments in cognitive control correlated only with depressive symptoms and not with anxiety scores. Still, it is important that given the high correlation between depression and anxiety scores, strong claims about the depression-specificity of our findings are not warranted. Finally, the association between the cognitive control impairments and depression in the present study does not inform about causality and therefore future research has to focus on the functional relationship between these constructs.

In conclusion, the results of this study offer further insight into the relationship between depression and impaired cognitive control. The findings indicate that while cognitive control was neither influenced by the task relevance of emotional information, nor influenced by the valence of the emotional information, MDD individuals were characterized by a general cognitive control impairment when switching between mental representations held in working memory. Examination of cognitive control as cognitive vulnerability factor underlying the onset,

maintenance, and recurrence of depressive episodes with accompanied expansions on treatment possibilities should be the scope of future research.

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Table 1. Group characteristics

	Group	
Variable	MDD	NDC
N	20	20
Age	39.70 (10.04)	45.20 (14.02)
Gender ratio (male/female)	8/12	9/11
Percentage currently on psychotropic medication*	85%	0%
Percentage with history of depression*	70%	0%
HRSD score*	22.95 (3.27)	0.50 (0.83)
BDI-II score*	32.20 (9.11)	5.05 (3.85)
STAI-T score*	62.10 (11.69)	36.60 (9.07)

Standard deviations are shown in parentheses.

HRSD = Hamilton Rating Scale for Depression; BDI-II = Beck Depression Inventory; STAI-T = State-Trait Anxiety Inventory.

* Indicates a significant difference ($p<.001$) between the depressed and non-depressed groups.

Table 2. Correlations between general cognitive control impairment, depression severity, symptom clusters of depression, rumination and anxiety.

	General switch cost	BDI Total	BDI Affective	BDI Somatic	BDI Cognitive	RRS Total	RRS Brooding	RRS Reflection	STAI-T
General switch cost	/	.325*	.393*	.300	.251	.336*	.140	.107	.274
BDI Total		/	.953**	.951**	.938**	.876**	.708**	.632**	.871**
BDI Affective			/	.879**	.854**	.833**	.642**	.578**	.791**
BDI Somatic				/	.808**	.843**	.683**	.596**	.826**
BDI Cognitive					/	.811**	.679**	.617**	.850**
RRS Total						/	.863**	.728**	.874**
RRS Brooding							/	.503**	.779**
RRS Reflection								/	.647**
STAI-T									/

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

BDI: Beck Depression Inventory; RRS: Response Rumination Scale; STAI-T: State-Trait Anxiety Inventory-Trait version

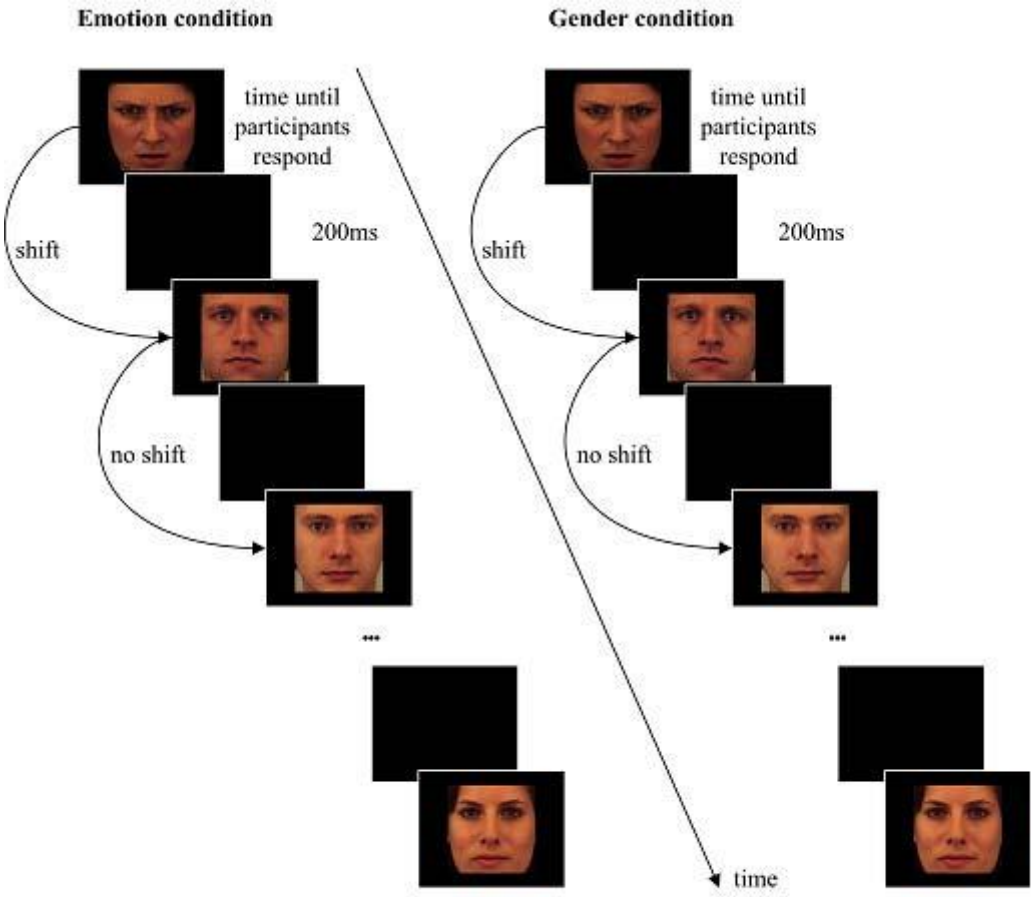


Figure 1. An example of a block of items and stimulus display.

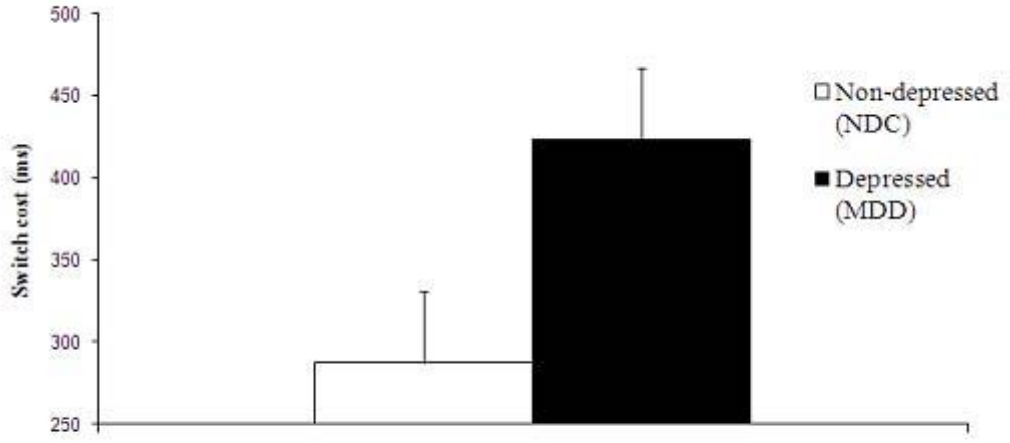
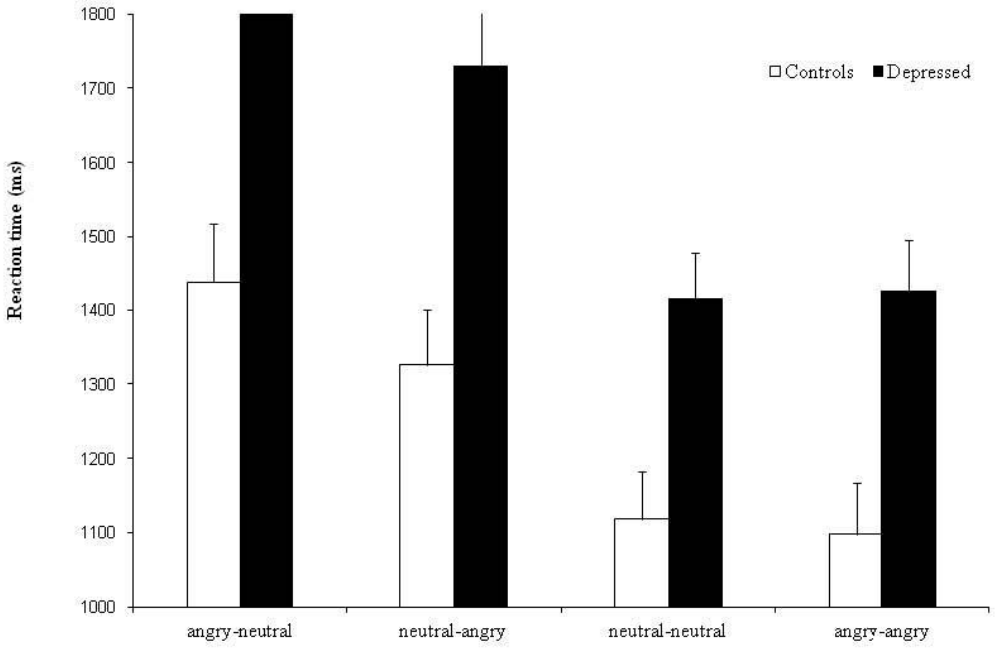


Figure 2. General switch cost in de depressed compared to the non-depressed control group (Mean and Standard Error).


Reaction time (ms)
1800
1700
1600
1500
1400
1300
1200
1100
1000
Controls
Depressed
angry-neutral
neutral-angry
neutral-neutral
angry-angry

5. FIGURE CAPTION

Figure 1. An example of a block of items and stimulus display.

Figure 2. General switch cost in the depressed compared to the non-depressed control group (Mean and Standard Error).

Figure 2. Reaction times in the depressed compared to the non-depressed control group in the emotion condition (Mean and Standard Error).

6. TABLE CAPTION

Table 1. Group characteristics

Table 2. Correlations between general cognitive control impairment, depression severity, symptom clusters of depression, rumination and anxiety.