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Cognitive control moderates the association between stress and rumination

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Abstract

Background and Objectives: A prospective design was used to examine whether inter-individual differences in cognitive control ability, for non-emotional and emotional material, play a moderating role in the association between the occurrence of a stressful event and the tendency to ruminate.

Methods: At baseline, the Internal Switch Task (IST) was administered in an undergraduate sample to measure the ability to switch attention between items held in working memory. Six weeks after baseline, self-report questionnaires were administered at 4 fixed moments during their first examination period at university, measuring stressors, rumination and depressive symptoms.

Results: Results revealed that impaired cognitive control, reflected in larger switch costs, moderated the association between stress and increased rumination. Interestingly, a larger switch cost when processing emotional material was specifically associated with increased depressive brooding in response to stress. No effects with reflective pondering were observed.

Conclusions: Implications for understanding the underlying mechanisms of rumination are discussed.

1. Introduction

Over the past two decades, rumination has evolved as a construct of growing interest to researchers and clinicans. *Rumination* is considered an emotion-regulation strategy in which an individual focuses repetitively on the causes, consequences, and meanings of negative mood states. In some models, rumination is thought to be a stable individual difference factor (Nolen-Hoeksema, 1991), but other models emphasize that rumination is also reactive to stress (Smith & Alloy, 2009). Although individuals believe that ruminating will help them to improve their mood, the tendency to ruminate can cause a fixation on problems and amplify negative affect. This inflexible self-focused attention has several detrimental effects (for reviews, see Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Watkins, 2008). Previous research has shown that rumination is associated with impaired problem solving, reduced task performance, and with negative affect. Furthermore, rumination is considered an important cognitive vulnerability factor for depression. Numerous studies have demonstrated that rumination in response to stress and dysphoria is associated concurrently with depressive symptoms and prospectively with the onset, duration, and severity of depressive symptoms, and with slower recovery from depression (Nolen-Hoeksema et al., 2008).

Recently, researchers have postulated that rumination has to be considered as a multidimensional construct. Factor analytic studies have found support for two different types of rumination (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). The first, *reflective pondering* is considered the more adaptive type of rumination and reflects the degree to which individuals engage in cognitive problem solving to improve their mood. The second, *depressive brooding*, is considered the more maladaptive type of rumination and reflects the degree to which individuals passively focus on the meaning and symptoms of distress. Mainly the depressive brooding type of rumination is associated with both high concurrent and high future depressive symptoms (Joormann, Dkane, & Gotlib, 2006; Treynor et al., 2003).

The observation that rumination has several detrimental effects has inspired research into the mechanisms underlying rumination. Recently, a wealth of research has begun to investigate the dynamic interplay between rumination and information processing impairments. Two distinct hypotheses have been postulated with regard to the relationship between rumination and information processing. On the one hand, it is held that a ruminative thinking style, continuously focusing on negative thought content, depletes cognitive resources required for problem solving and task performance (Watkins & Brown, 2002). On the other hand, it has been proposed that information processing impairments contribute to ruminative tendencies (De Raedt & Koster, 2010; Koster, De Lissnyder, Derakhshan, & De Raedt, 2011; Whitmer & Banich, 2007). These latter models hold that cognitive control impairments may contribute to higher levels of rumination upon encounter of stress. Although there is empirical support for the first proposal (see Watkins, 2008), there only is emerging research on the second proposal. This is remarkable because an enhanced understanding of factors contributing to rumination may allow for targeted interventions to reduce the development or magnification of depressive symptoms. We first describe the ideas and research related to the second proposal.

The ability to control cognition and to disengage from negative cognitions is thought to be a crucial information processing factor related to the tendency to ruminate (Koster et al., 2011). *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). Impaired cognitive control mechanisms of working memory hamper cognitive control of irrelevant information (e.g., negative thoughts), enhancing ruminative thinking. Therefore, Koster et al. (2011) argued that impaired cognitive control is a risk factor for prolonged rumination in confrontation with stressors and a negative mood state. Indeed, rumination is related to impaired cognitive control when processing non-emotional information (Davis & Nolen-Hoeksema, 2000; De Lissnyder, Derakshan, De Raedt, & Koster, in press-a; Whitmer & Banich, 2007) as well as emotional information (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; De Lissnyder, Koster, & De Raedt, in press-b; Joormann, 2006; Joormann & Gotlib, 2008; Joormann et al., 2010; Lau, Christensen, Hawley, Gemar, & Segal, 2007). Previous research showed that particularly depressive brooding was related to the cognitive control impairments. However, these studies have used cross-sectional designs and are unable to make inferences about the causal relationship between information processing impairments and rumination. Therefore, we set out to test the hypothesis that impaired cognitive control exacerbates rumination, using a prospective design examining whether inter-individual differences in cognitive control ability, for non-emotional and emotional material, plays a moderating role in the association between the occurrence of a stressful event and the tendency to ruminate.

In the past, research into cognitive control has mainly employed tasks which measure cognitive control for externally presented stimuli. However, it is questionable whether examining cognitive control for externally presented stimuli is the most adequate way to target the link with rumination as the tendency to ruminate is defined as persistently focusing on *internal* negative thoughts. 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 rumination, it would be interesting to investigate cognitive control ability for internal mental representations held in working memory. An interesting task for this purpose is the Internal Switch Task (IST) (De Lissnyder et al., in press-b; De Lissnyder, Koster, & De Raedt, submitted). Garavan (1999) as well as Gehring and colleagues (Gehring, Bryck, Jonides, Albin, & Badre, 2003) have used a paradigm to examine cognitive control for internal mental representations held in working memory. Recently, Chambers, Lo, and Allen (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 Switch Task (IST). Research indicates that the IST is a reliable and valid measure of internal cognitive control (De Lissnyder et al., submitted).

Cognitive control consists of a number of different sub-processes (Miyake et al., 2000). The cognitive control functions related to rumination in the literature are mainly inhibition and switching (e.g., Davis & Nolen-Hoeksema, 2000; Joormann, 2006; Whitmer & Banich,2007), as well as updating (e.g., Bernblum & Mor, 2010; Joormann & Gotlib, 2008). A few studies have tried to assess and to disentangle the cognitive control functions, inhibition and switching, in relation to rumination in one single design (De Lissnyder et al., in press-a; De Lissnyder et al., 2010; Whitmer & Banich, 2007). However, recent evidence indicates that different cognitive control functions, such as inhibition and switching, are highly interrelated (Koch, Gade, Schuch, & Philipp, 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. Although a number of more specific cognitive operations may be responsible for the observation of impaired switching between internally held mental representations, the IST provides behavioural data directly related to switching between representations in working memory, whereas this task does not allow to specify which precise factors contribute to this observation. 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 in working memory. In the switching literature, the reaction time switch cost is typically referred to as the difference in reaction time between switch and no-switch (or repeat) trials (Monsell, 1996).

In sum, the current study was conducted to examine whether inter-individual differences in internal switching ability plays a moderating role in the association between the occurrence of a stressful event and the tendency to ruminate. The study was conducted using a never-depressed healthy sample as their stress-reactivity is not influenced by former depressive episodes. These participants were undergraduates facing their first academic examination period. The procedure involved an initial assessment in which the IST was administered to measure switching ability between internal mental representations held in working memory and baseline levels of rumination and stress where obtained. Subsequently, six weeks after baseline, self-report questionnaires were administered at 4 fixed moments during their first examination period, measuring rumination and the occurrence of stressors.

The aims of the current study were three-fold:

(1) To investigate whether inter-individual differences in internal switching ability moderate the association between stress and rumination. We hypothesized that larger switch costs related to emotional material (T1) will be associated with increased rumination in response to stress (T2-T5).

(2) To investigate the moderating impact of inter-individual differences in internal switching ability in the activation of the differential types of rumination in response to stress. We hypothesized that the internal switching impairments (T1) will be specifically associated with increased depressive brooding in response to stress (T2-T5). No effects with reflective pondering were expected.

(3) To investigate the valence-specificity of internal switching ability for emotional material. Given that rumination is defined as persistently focusing on negative thoughts, we hypothesized that higher switch costs (T1) related to switching from

negative to neutral information (angry-neutral switch, see below), compared to switching from neutral to negative information (neutral-angry switch, see below), will be associated with increased rumination/depressive brooding in response to stress (T2-T5).

2. Method

2.1. Participants

Thirty-seven first year undergraduates of Ghent University (31 females, 6 males) ranging from 17 to 24 in age (*M*=19.73, *SD*=1.56) participated in return for financial compensation. At baseline, the mean score of depressive symptoms was 5.51 (*SD*=5.11) (BDI-II-NL, Van Der Does, 2002).

2.2. Materials

2.2.1. Self-report questionnaires

2.2.1.1. Beck Depression Inventory-Second edition (BDI-II; Beck, Steer, & Brown, 1996; BDI-II-NL, Van der Does, 2002). The BDI-II-NL is a 21-item self-report questionnaire which assesses the severity of a range of affective, somatic and cognitive symptoms of depression. Individuals rate each symptom on a scale ranging from 0 to 3. The acceptable reliability and validity of the BDI-II have been well documented (Beck et al., 1996).

2.2.1.2. Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991; RRS-NL, Raes et al., 2009) The RRS-NL is a 26-item self-report questionnaire which assesses rumination and consists of items that describe responses to a depressed mood that are focused on the self, symptoms, or consequences of the 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 RRS scores and subscale scores for reflective pondering and depressive brooding were calculated. The RRS is a reliable and valid measure of rumination with good psychometric properties (Treynor et al., 2003).

Adverse Events Questionnaire (AEQ, Carver, 1998). This is a self-report questionnaire especially designed for a student population and is intended to track the occurrence of adverse events that commonly occur in students' lives. Participants are asked to indicate if they have had a 'relatively major bad experience' in academic, relationships or other aspect of life during last week by answering No = 0 or Yes = 1.

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, Flykt, & Öhman, 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 intense - 9=completely intense) 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, De Raedt, Leyman, & Verschuere, 2008).

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, a *non-emotional* (hereafter referred to as gender condition) and an *emotional* 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). Due to the sequence of the faces, there were 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 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 trials consisted of 3 blocks of items and the experimental trials 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 baseline (T1) , the IST was administered to measure internal switching ability. Participants completed self-report questionnaires, measuring rumination, stressors and depressive symptoms, at the end of the laboratory session to avoid mood priming effects. Subsequently, six weeks after baseline, the same internet self-report questionnaires were administered again every week (T2-T5) during the first examination period at university. Participants are asked to fill in the questionnaires regarding last week.

2.4. Data-analytic strategy: multilevel modelling

The data comprised a multilevel (or hierarchically nested) data structure in which ruminative responses to stress over 4 time moments (Level 1) were nested within individuals (Level 2). We investigated whether impaired cognitive control at T1, reflected by larger switch costs, moderated the association between stress and rumination at T2-T5. The data were analyzed with a series of multilevel regression analyses using the program HLM (Raudenbush, Bryk, & Congdon, 2004; Version 6.01). The Level-1 predictor AEQ was dummy coded and entered into the equations as uncentered; Level-2 predictors (i.e., switch costs) were standardized and grand mean centered to allow for comparisons across Level 2 units and for clearer interpretation of coefficients. The significance level was set at $\alpha<.05$. Full maximum likelihood estimation was used for all models. Effect sizes r were reported and calculated according to the formula $r = r_D \sqrt{(1 + r_I/2)}$, with $r_D = \sqrt{(t^2 / t^2 + n-2)}$, r_I = intraclass correlation (which is the proportion of variation in the outcome measure that is accounted for by the level-2 predictors), t = t-value from the multilevel regression analysis, and n = number of participants (see Kenny, Kashy, & Cook, 2006). Effect sizes r of .1 are considered small, .3 medium, and .5 large effects (see Cohen, 1988).

To test our hypotheses, the following set of analyses was executed. First, a baseline model was run to calculate how much variance in rumination (total score, depressive brooding respectively reflective pondering) was attributable to variation between participants (Level 2), and to evaluate whether a multilevel approach is appropriate. Second, the level-1 predictor AEQ was entered into the model to investigate the (Level-1) relationship between stress and rumination. Third, it was investigated how this Level-1 association varied as a function of the Level-2 predictor switch cost. This is referred to as a cross-level interaction, as this concerns an analysis of how a relationship at Level 1 varies as a function of a variable at Level-2, or a slopes-as-outcomes analysis (see Nezlek, 2001). Specifically, the respective switch cost parameters (emotion and gender) were entered simultaneously into the model to investigate whether differences between participants in switch costs (Level-2) moderated the Level-1 relationship between stress and rumination. Also, baseline levels (T1) of rumination (RRS total score, depressive brooding, or reflective pondering) and depression (BDI) were entered as Level-2 predictors to control for initial rumination scores and depressive symptoms. The following cross-level model was analyzed:

Level 1: $Y_{ij} = \beta_{0j} + \beta_{1j}(\text{AEQ: stress}) + r_{ij}$

At Level 2, Level 1 coefficients were then modelled as a function of baseline internal switching impairments or switch costs, while controlling for baseline levels of rumination and depression:

$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{IST: switch cost emotional information}) + \gamma_{02}(\text{IST: switch cost non-emotional information}) + \gamma_{03}(\text{RRS: baseline rumination}) + \gamma_{04}(\text{BDI: baseline depression}) + u_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{IST: switch cost emotional information}) + \gamma_{12}(\text{IST: switch cost non-emotional information}) + u_{1j}$.

We assumed that participants differed randomly in their overall level on the dependent variables (random intercepts), and we allowed that participants differed randomly in the regression coefficients of the Level 1 variable (random slopes). If a random error term was detected to be non significant, it was deleted from the model and the independent variable constrained to be fixed across participants (Nezlek, 2001).

3. Results

3.1. Descriptives

Mean scores, standard deviations and Cronbach's alphas of the self-report questionnaires BDI-II-NL, RRS-NL and AEQ are listed in Table 1. For the analyses of the IST, median scores of reaction times 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 (see De Lissnyder et al., in press; De Lissnyder et al., submitted). Reported numbers of the faces in each category were highly accurate (*M*=88%, *SD*=9%). Mean scores, standard deviations and range for the measures of the Internal Switch Task are listed in Table 2.

(Table 1 about here)

(Table 2 about here)

3.2. Multi level modelling

3.2.1. Rumination (RRS total score)

The baseline model indicated that there was a significant amount of unexplained variance in participants' total rumination scores as a significant chi-square associated with the variance component u_{0j}, $\chi^2(36)=1368.69$, $p<.0005$, was found. Estimation of the intraclass correlation indicated that 90% of the variance in total rumination was due to variation between subjects, which indicates that a multilevel approach is warranted. Next, the level-1 predictor (AEQ) and Level-2 predictors (switch costs for both emotional and non-emotional condition simultaneously, baseline rumination, baseline depression) were entered into the model. It was found that baseline switch costs in the emotional condition tended to moderate the association between stress and rumination. In particular, the association between stress and rumination was stronger when individuals showed larger switch costs in the emotional condition [Coefficient=5.80, *SE*=3.12, $t(140)=1.86$, effect size *r*=, *p*=.07], after controlling for baseline rumination (RRS total score) and baseline depression (BDI) (see Table 3). No significant moderating effect of switch cost related to non-emotional information was found.

(Table 3 about here)

To further investigate the moderating effect of valence-specific internal switching impairments on total rumination score in response to stress, switch costs (T1) related to specifically switching from negative to neutral information (angry-neutral switches), compared to switching from neutral to negative information (neutral-angry switches), the moderating role of angry-neutral switches and neutral-angry switches in the emotion condition were investigated. Analyses revealed no valence-specific effects.

3.2.2. Depressive brooding (RRS)

An inspection of the baseline model with no predictors indicated that 79% of the variance in depressive brooding was due to variation between subjects, warranting a multilevel approach. Also, chi-square associated with the variance component u_{0j}, $\chi^2(36)=609.27$, $p<.0005$, indicated a significant amount of unexplained variance in participants' depressive brooding scores. To test our hypotheses, the Level-1 predictor (AEQ) and Level-2 predictors (switch costs for both emotional and non-emotional condition simultaneously, baseline rumination, baseline depression) were entered into the model. It was found that baseline switch costs in the emotional condition moderated the association between stress and depressive brooding. In particular, the association between stress and depressive brooding was stronger when individuals showed larger switch costs in the emotional condition [Coefficient=3.21, *SE*=1.02, $t(140)=3.13$, effect size $r=.44$, $p=.003$], after controlling for baseline depressive brooding (RRS brooding) and baseline depression (BDI) (see Table 3). No significant moderating effect of switch cost related to non-emotional information was found (see Table 3).

To investigate further the moderating effect of valence-specific internal switching impairments on depressive brooding in response to stress, the moderating role of angry-neutral switches and neutral-angry switches in the emotion condition were investigated. Analyses revealed no valence-specific effects.

3.2.3. Reflective pondering (RRS)

Initial analyses indicated that 85% of the variance in reflective pondering was due to variation between participants. Chi-square associated with u_{0j} was significant, $\chi^2(36)=900.71$, $p<.0005$. Next, the level-1 predictor AEQ and the Level-2 predictors (i.e., switch costs for both emotional and non-emotional condition simultaneously, baseline reflective pondering, baseline depression) were entered in the model. The results showed that the association between stress (AEQ) and reflective pondering (RRS) was not moderated by switch cost, after controlling for baseline depressive brooding (RRS brooding) and baseline depression (BDI) (see Table 3).

4. Discussion

In the current study, we have tested the hypothesis that impaired cognitive control exacerbates rumination using a prospective design examining whether switching impairments between internal mental representations held in working memory moderates the association between the occurrence of a stressful event and the tendency to ruminate. The main findings were that (1) impaired internal switching for emotional material moderated the association between stress and increased rumination (at trend level), (2) the internal switching impairments were specifically associated with increased depressive brooding, and not with reflective pondering, following the occurrence of a stressor, and (3) no valence-specific moderating switching effects were observed.

At the theoretical level, this study adds to a growing literature showing that impaired cognitive control is related to rumination (e.g., De Lissnyder et al., 2010; De Lissnyder et al., in press-a; De Lissnyder et al., in press-b; De Lissnyder et al., submitted; Joormann, 2006; Joormann et al., 2010; Joormann & Gotlib, 2008; Lau et al., 2007; Whitmer & Banich, 2007). However, these studies have used cross-sectional designs and are unable to make inferences about the causal relationship between information processing impairments and rumination. In most models and research it is held and found that rumination depletes cognitive resources (Watkins & Brown, 2002). However, the results based on our prospective design indicate that there also is a reverse relation, where impaired information processing contributes to rumination. Our results are in line with a recent prospective study (Zetschke & Joormann, 2011) using other tasks that tap more into external attention that have also provided support for the idea that cognitive control predicts rumination (as well as depressive symptoms). These findings support the idea that information processing impairments contribute to ruminative tendencies (De Raedt & Koster, 2010; Koster et al., 2011; Whitmer & Banich, 2007). Reduced cognitive control seems to be an important cognitive process that underlies the role of rumination in exacerbating and maintaining psychological distress. Thus, there now is evidence for a reciprocal relation between rumination and cognitive control: Cognitive control influences rumination and rumination influences cognitive control. It seems likely that in real life this reciprocal relationship can hamper emotion regulation severely.

Our results showed that impaired internal switching specifically for emotional material, moderates the association between stress and rumination, at trend level. Additional analyses revealed no valence-specific switching effect (negative-neutral) when confronted with emotional material. It is still unclear if the cognitive control impairments related to rumination are specific to the kind of information being controlled as there is research evidence for impaired cognitive control when processing non-emotional material (e.g., De

Lissnyder et al., in press-a; Whitmer & Banich, 2007) as well as emotional material (e.g., De Lissnyder et al., 2010; De Lissnyder et al., in press-b; De Lissnyder et al., submitted; Joormann, 2006; Joormann & Gotlib, 2008; Joormann et al., 2010). Our findings indicate that the tendency to ruminate in response to stress in an unselected sample is related to impaired cognitive control specifically for emotional information. However, no valence-specific effects with regard to the sequence of faces were observed for this predictive relation. Based on our results with an unselected sample and current findings reported in the literature with mainly dysphoric and depressed samples, we argue that it would be interesting for future research to investigate if the interaction between impaired cognitive control, negative mood, and distress mainly causes the tendency to ruminate about emotional, and mainly, negative information. It could also be that the effect of the valence-specificity of the cognitive control impairments related to rumination increases with the temporal unfolding of vulnerability for depression.

Interestingly, our results showed that impaired internal switching specifically for emotional information moderates the association between stress and depressive brooding, with no such relation being observed for reflective pondering. This finding extends our previous work showing that depressive brooding is more strongly related to cognitive control impairments than either reflective pondering (De Lissnyder et al., 2010; De Lissnyder et al., in press-a; De Lissnyder et al., submitted). The finding that it was mainly the maladaptive component of rumination, depressive brooding, that was related to impaired cognitive control for emotional information is important from a vulnerability for depression perspective, as it is mainly depressive brooding that is associated with both high concurrent and high future depressive symptoms (Joormann, Dkane, & Gotlib, 2006; Treynor et al., 2003). Undergraduates who ruminate are at risk to develop depression and we suggest that future research has to focus on the causal relationship between impaired cognitive control, the different types of rumination and the development of depressive symptoms.

The further elucidation of the mechanisms underlying rumination is of importance from a translation clinical research perspective. That is, a more precise understanding of the cognitive impairments in depression may in the future allow to examine its precise role in the pathophysiology of depression and potential ways to remediate such problems (De Raedt, Koster, & Joormann, 2010). Several existing (cognitive behaviour therapy; Clark & Beck, in press) as well as new interventions (cognitive training regimes; MacLeod, Koster, & Fox, 2009; Siegle, Ghinassi, & Thase, 2007) strengthen cognitive control and may reduce rumination and risk for depression.

In future research in this area some of the restrictions of the present study could be taken into account. First, only self-report measures that required participants to indicate whether or not a stressful event has occurred were used to measure stress. More sophisticated methods of analyses such as interviewing procedures may provide more comprehensive assessments of stress (e.g. McQuaid, Monroe, Roberts, Johnson, & Garamoni, 1992). Another possible limitation linked to the measurement of stress is that the amount of stressful events reported is not large. Thus there is limited variability in the number of stressors reported which could be due to our use of a single-item measurement of stress. It seems that only these students who perceived the exams as a major negative event answered “yes”. Importantly, not the absolute number of stressors is important, but the effect of the interaction with cognitive control, which revealed to be a significant predictor of rumination. A second limitation is the lack of follow-up measures of depressive symptoms and rumination after a longer period of time. The lack of follow-up measures impedes conclusions on long-term effects, such as relations between impaired cognitive, rumination, and later development of depressive symptoms. Finally, future studies should utilize larger sample sizes. Such an approach would allow more powerful evaluation of the interactive model of the relationship between stress, cognitive control and rumination.

In conclusion, the current study provides support for the idea that inter-individual differences in cognitive control ability for emotional material moderates the tendency to ruminate in response to a stressful life event. These results are of importance to the understanding of impaired information processing mechanisms underlying rumination.

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Figure caption.

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

Table caption.

Table 1. Mean scores (and standard deviation) with Cronbach's alpha (α) of all self report questionnaires on T1-T5 (N = 37).

Table 2. Mean scores, standard deviations, and range for the measures of the Internal Shift Task (IST).

Table 3. Hierarchical linear models assessing the moderating impact of switch cost upon the relation between stress and rumination**.**

Table 1.
Mean scores (and standard deviation) with Cronbach's alpha (α) of all self-report questionnaires on T1-T5 (N = 37).

	T1	T2	T3	T4	T5	
	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)	α
RRS/ Total scores	50.78 (12.32)	44.51 (12.93)	43.13 (13.36)	41.70 (13.04)	41.84 (13.83)	.98
RRS/ Depressive Brooding	10.29 (3.58)	8.86 (2.97)	8.67 (2.82)	8.51 (2.92)	8.70 (3.47)	.93
RRS/ Reflective Pondering	9.62 (3.50)	8.13 (3.21)	7.89 (3.37)	7.48 (2.98)	7.62 (2.83)	.93
BDI-II	5.51 (5.11)	8.10 (6.41)	7.32 (6.29)	5.29 (7.30)	3 (4.3)	.97
AEQ	Yes:5 No:32	Yes:5 No:32	Yes:5 No:32	Yes:3 No:34	Yes:2 No:32	

Note: Higher scores are indicative of higher levels of rumination, more depressive symptoms and more adverse events.
RRS: Response Rumination Scale, BDI-II: Beck Depression Inventory, AEQ: Adverse Events Questionnaire

Table 2.
Mean scores, standard deviations, and range for the measures of the Internal Shift Task (IST)

	Mean	*SD*	*Minimum*	*Maximum*	*Range*
Global (over conditions)					
RT global	1379	327	840	2139	1298
RT no switch	1157	274	717	1699	982
RT switch	1614	386	989	2691	1702
RT switch cost	457	243	112	1184	1072
Emotion condition					
RT emotion condition	1424	376	747	2437	1690
RT no switch	1193	328	548	1934	1386
RT switch	1638	399	904	2595	1691
RT switch cost	444	225	101	1202	1101
Gender condition					
RT gender condition	1326	302	748	2015	1267
RT no switch	1118	259	619	1710	1091
RT switch	1574	414	933	2895	1962
RT switch cost	456	303	44	1542	1498

Table 3.
Hierarchical linear models assessing the moderating impact of switch cost upon the relation between stress and rumination

	Coefficient	*SE*	*t*
RRS-total			
Intercept (γ_{00})	42.78	1.53	27.97***
Switch cost emotional information (γ_{01})	.34	1.79	.19
Switch cost neutral information (γ_{02})	1.33	2.70	.49
Baseline rumination (total score) (γ_{03})	8.19	1.72	4.75***
Baseline depression (BDI) (γ_{04})	2.64	1.40	1.88†
Stress (AEQ) (γ_{10})	.96	.95	1.02
Stress (AEQ) x Switch cost emotional information (γ_{11})	5.80	3.12	1.86†
Stress (AEQ) x Switch cost neutral information (γ_{12})	.47	1.49	.32
RRS-depressive brooding			
Intercept (γ_{00})	8.62	.32	26.94***
Switch cost emotional information (γ_{01})	.20	.38	.53
Switch cost neutral information (γ_{02})	.19	.36	.53
Baseline depressive brooding (γ_{03})	1.80	.41	4.39***
Baseline depression (BDI) (γ_{04})	.52	.30	1.73†
Stress (AEQ) (γ_{10})	1.11	.43	2.60*
Stress (AEQ) x Switch cost emotional information (γ_{11})	3.21	1.02	3.13**
Stress (AEQ) x Switch cost neutral information (γ_{12})	-.25	.69	-.37
RRS-reflective pondering			
Intercept (γ_{00})	7.77	.38	20.69***
Switch cost emotional information (γ_{01})	.18	.45	.39
Switch cost neutral information (γ_{02})	-.22	.75	-.30
Baseline reflective pondering (γ_{03})	1.81	.40	4.51***
Baseline depression (BDI) (γ_{04})	.05	.33	.16
Stress (AEQ) (γ_{10})	.08	.25	.32
Stress (AEQ) x Switch cost emotional information (γ_{11})	.28	.73	.38
Stress (AEQ) x Switch cost neutral information (γ_{12})	-.49	.49	-1.00

Note. AEQ = Adverse Event Questionnaire; RRS = Response Rumination Scale; BDI = Beck Depression Inventory
† $p < .10$ * $p < .05$; ** $p < .005$; *** $p < .0005$