Worrying and Rumination are both associated with reduced Cognitive Control

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Abstract

Persistent negative thought is a hallmark feature of both major depressive disorder and generalized anxiety disorder. Despite its clinical significance, little is known about the underlying mechanisms of persistent negative thought. Recent studies suggest that reduced cognitive control might be an explanatory factor. We investigated the association between persistent negative thought and switching between internal representations in working memory, using the Internal Shift Task (IST). The IST was administered to a group of undergraduates, classified as high-ruminators versus low-ruminators, or high-worriers versus low-worriers. Results showed that high-ruminators and high-worriers have more difficulties to switch between internal representations in working memory as opposed to low-ruminators and low-worriers. Importantly, results were only significant when the negative stimuli used in the IST reflected personally relevant worry-themes for the participants. The results of this study indicate that rumination and worrying are both associated with reduced cognitive control for verbal information that is personally relevant.

Keywords: Persistent negative thought, worry, rumination, cognitive control, shifting

1. Introduction

Worldwide, major depressive disorder (MDD) and generalized anxiety disorder (GAD) are the most prevalent psychiatric disorders among primary care patients (Ormel, VonKorff, Ustun, Pini, Korten, & Oldehinkel, 1994). Although affective disorders show high relapse rates, current treatments are based on treating symptoms (post onset), rather than focusing on prevention. In order to develop preventive measures and effective treatment programmes, we need a better understanding of the causes and sustaining factors of MDD and GAD. One of the transdiagnostic characteristics these disorders have in common is persistent negative thought. In MDD, this persistent thinking is called rumination. Ruminative thoughts often deal with negative *past* events, such as failures, losses, etc., and focus on the origin, causes, and consequences of negative emotions and the symptoms of depression (Nolen-Hoeksema, 1991). In GAD, on the other hand, thoughts are typically related to possible negative events in the *future* and strategies to prevent such events from occurring. This process is referred to as worrying (Borkovec & Inz, 1990).

Although factor analysis has shown that rumination and worrying questionnaires target two distinct constructs, there is a strong correlation between both constructs (Fresco, Frankel, Mennin, Turk, & Heimberg, 2002), and the subtle difference in content remains debatable. For example, a substantial proportion of worrying is about past events (Molina, Borkovec, Peasy, & Pearson, 1998), whereas depressive rumination might just as well entail worrying about future implications of depressive symptoms (Nolen-Hoeksema, 1991). In accordance with several other authors (e.g. Muris, Roelofs, Meesters, & Boomsma, 2004; Segerstrom, Tsao, Alden, & Craske, 2000; Watkins,

Moulds, & Mackintosh, 2005), we assume that worrying and rumination are similar cognitive processes described in a different research context. We will therefore use the term persistent negative thinking, with reference to both worrying and rumination.

Besides having an adverse impact on affective states (McLaughlin, Borkovec, Sibrava, 2007, Nolen-Hoeksema, 2000; Purdon & Harrington, 2006), persistent negative thought has physiological implications such as increased cardio-vascular, endocrinological, immunological, and neurovisceral activity (Brosschot, Gerin, & Thayer, 2006). However, despite the clinical significance of persistent negative thought, its underlying mechanisms remain poorly understood. The purpose of our study is to gain more insight into this matter by clarifying the interrelationship between basic cognitive functioning and persistent negative thought. We will therefore investigate the association between cognitive control and both worrying and rumination.

An important potential underlying cognitive mechanism discussed in the context of anxiety and depression is a valence-specific attention bias. Several studies have shown that depressed persons have an impaired ability to divert their attention away from negative information (for a review, see De Raedt & Koster, 2010). This disengagement bias has been shown to be more pronounced in individuals who have a strong tendency to ruminate (Donaldson, Lam, & Mathews, 2007). Anxious persons, on the other hand, have been reported to have an attention bias towards threat-related material at earlier stages of information processing (for a review, see Bar-Haim, Lamy, Pergamin, Bakersman-Kranenburg, & van Ijzendoorn, 2007), and worry-induction seems to facilitate this bias (Oathes, Squillante, Ray, & Nitschke, 2010).

Importantly, recent research suggests that cognitive control impairments play a major role in the occurrence of both valence-specific attention bias and persistent negative thought (e.g. De Lissnyder, Koster, Derakshan, & De Raedt, 2010). Studies investigating cognitive control generally distinguish between three factors of cognitive control: inhibition, shifting, and updating. Previous findings have successfully linked these different facets of cognitive control to rumination, but worrying is much less investigated. The inhibition function, i.e., the capacity to avoid interference by task-irrelevant stimuli (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000), seems to be impaired in rumination (Whitmer & Banich, 2007), in particular inhibition of negative material (De Lissnyder et al., 2010; Joormann, 2006). Several researchers have therefore suggested that valence-specific inhibition impairments have a causal role in the increased elaboration of negative material in rumination (e.g. Hester & Garavan, 2005). In contrast to rumination, less research exists on the interrelationship between worrying and the inhibition function. This despite the fact that worrying has been theoretically linked to deficient inhibition by Eysenck, Derakshan, Santos, and Calvo (2007), who put forward that inhibition impairments produce worrying in anxious individuals. An exception is a study by Brown (2009) indicating that worrying is indeed associated with an impaired ability to inhibit negative words. Because of this defective inhibition function, irrelevant negative material is suggested to enter working memory more readily.

In contrast to the inhibition function, the updating function (i.e., monitoring incoming information in working memory by replacing no-longer-relevant information with new, more relevant information) and shifting function (i.e., the capacity to continually adjust our focus of attention towards the most relevant task stimuli) (Miyake

et al., 2000), have been far less investigated in experimental psychopathology research. One study by Joormann and Gotlib (2008) indicated that rumination is associated with increased interference from irrelevant negative material while updating the content of working memory. Other studies have shown a positive correlation between the tendency to ruminate and the number of perseverative errors on shifting tasks using non-emotional material (Davis & Nolen-Hoeksema, 2000; Whitmer & Banich, 2007). Two studies using emotional stimuli found general (De Lissnyder et al., 2010) versus valence-specific (De Lissnyder, Koster, and De Raedt, 2012) impairments in students with a tendency to ruminate. The relationship between worrying and the updating and shifting function has not been studied directly. Since we anticipate that rumination and worrying are similar processes, we expect worrying to be associated with the same cognitive control impairments as those found in rumination.

All studies to date have used pictorial stimuli (e.g. geometric figures and faces) to investigate the relationship between cognitive control and persistent negative thought. This is surprising, given the verbal nature of persistent negative thought. For this reason, we examined the association between cognitive control and persistent negative thought in the context of verbal instead of pictorial stimuli. To the best of our knowledge, we are the first to investigate impaired cognitive control with verbal material. Since words are more open to interpretation than for example faces, we had to make sure that the negative verbal stimuli presented in the experiment had a negative connotation for the participants. For this reason the negative words in the experiment had to be personally relevant. We define *personal relevance* as negative words that are effectively related to themes our participants worry about. We did this in accordance with previous studies indicating that

people react more strongly to personally relevant stimuli (Oathes, Siegle, & Ray, 2011; Siegle, Steinhauer, Carter, Ramel, & Thase, 2003). We selected worry-themes based on a pilot study which revealed that respondents worried primarily about fear of failure and relationships. This is in accordance with other studies that have investigated worry domains (Brown, 2009; Stöber & Joormann, 2001; Tallis, Eysenck, & Mathews, 1992). Using negative words related to these themes also enabled us to examine whether cognitive control impairments occur in ruminators and worriers in general, or only in those for whom these themes are relevant.

It is important to note that cognitive research within this domain generally uses experimental paradigms that measure the capacity to switch attention between *external* stimuli. However, especially the ability to control *internal* negative information could be an important process underlying persistent negative thought. Therefore, we adopted a paradigm that measures the capacity to switch attention between *internal* representations in working memory, i.e., the Internal Shift Task (IST; Garavan, 1998; Chambers, Lo, & Allen, 2008). A psychometric evaluation of the IST with emotional facial expressions by De Lissnyder, Koster, and De Raedt (submitted) indicated that the IST is a reliable task for measuring the Internal Switching Cost (ISC), i.e., the difference in RT between switch and no-switch (or repeat) sequences (Monsell, 2003). However, note that the IST does not provide a 'pure' measure of switching. Framed in terms of functional task demands, participants have to switch between internal representations held in working memory, and the IST provides a behavioral measure of this cognitive control operation. Like many tasks used in the context of executive functions and cognitive control, performance on the IST is dependent on multiple cognitive operations (Greve, Stickle,

Love, Bianchini, & Stanford, 2005). Therefore, we frame IST performance in general terms of cognitive control instead of further specifying its separate components. In a recent study, De Lissnyder et al. (2012) examined the ISC in dysphoric students and students with a tendency to ruminate, using the IST with pictorial stimuli (photographs of angry versus neutral faces). The main finding was that depression was not related to reduced cognitive control, though rumination was. Moreover, the cognitive control impairments for ruminators were most pronounced when negative information was held in working memory (De Lissnyder et al., 2012). In the current study, we aimed to determine whether rumination was associated with (the same) cognitive control deficits when verbal instead of pictorial stimuli were used, and whether worriers exhibited similar cognitive control deficits as ruminators.

To recapitulate, the purpose of the present study was to investigate whether worrying and rumination are associated with reduced cognitive control, and whether this possibly reduced cognitive control is affected by the personal relevance of the stimuli.

2.   Method

2.1. Participants

84 students (56 women and 28 men), with an average age of 19 years ($SD = 2.39$) were selected from a sample of undergraduates ($N = 310$) who were taking an introductory psychology course. The selection was based on their scores on the Penn-State Worry Questionnaire (PSWQ) and the Ruminative Response Scale (RRS): only students with scores in the top 10% (high-worriers and high-ruminators) and the bottom 10% (low-worriers and low-ruminators) of scores participated in the actual study. The

negative words we used in the IST were selected according to two themes: fear of failure and relationships. To make sure these words had a negative connotation for the participants, we only included participants who indicated they worried about fear of failure and relationships, leaving a group of 62 participants (out of this group of 84 students). As we performed analyses on rumination and worry in the same overall sample based on high versus low scores, there was an overlap of 38.71% between the individuals in the worry and rumination groups: 14 participants with high scores on both the PSWQ and the RRS and 10 participants with low scores on both the PSWQ and the RRS, on a total of 62 participants. There was also a positive correlation between the scores on the PSWQ and RRS, $r = .55$, $p < .001$. For additional details on the separate rumination and worry groups, see results section below. The study was approved by the Ethics Committee of the Vrije Universiteit Brussel (VUB).

2.2. Material

2.2.1. Self- Report Questionnaires

The Penn-State Worry Questionnaire (PSWQ). The PSWQ (Meyer, Miller, Metzger, & Borkovec, 1990; Authorized Dutch Version: Van Rijsoort, Vervaeke, & Emmelkamp, 1997) is a 16-item questionnaire that assesses the tendency to worry. The items are rated on a 5-point scale for the degree to which they characterize the participant. The Dutch version of the PSWQ has an adequate reliability and high internal consistency (Kerkhof, Hermans, Figee, Laeremans, Peters,et al., 2000; Van Rijsoort, Emmelkamp, &Vervaeke, 1999).

The Ruminative Response Scale (RRS). The RRS (Treynor, Gonzalez, & Nolen-Hoeksema 2003; Authorized Dutch Version: Raes, Schoofs, Hoes, Hermans, Van Den Eede, & Franck, 2009) consists of items measuring the tendency to ruminate when in a depressed mood. Each item is rated on a 4-point scale ('almost never' to 'almost always'). A study by Raes et al. (2009) showed that the Dutch version of the RRS with 26 items has adequate reliability and good validity.

The State –Trait Anxiety Inventory (STAI). The STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983; Authorized Dutch Version: Van der Ploeg, 2000) is a 40-item self-report scale designed to measure two distinct anxiety concepts: state anxiety (A-state) and trait anxiety (A-trait). Item scores range from 1 to 4. Good validity is reported for the Dutch version of the STAI (Van der Ploeg, 2000).

Beck Depression inventory (BDI-II). The BDI-II (Beck, Steer, & Brown, 1996; Authorized Dutch Version: Van der Does, 2002) is a self-rating measure for severity of depression. It consists of 21 items measuring depressive symptoms, as defined by the DSM-IV (APA, 1994). Participants are asked to mark the statements that describe best how they felt during the 2 weeks prior to participation, with item scores ranging from 0 to 3. Construct validity and reliability of the Dutch version are satisfactory (Van der Does, 2002).

2.2.2. Apparatus and Stimuli of the IST

The IST was conducted on IBM-compatible Pentium 4 personal computers with a

17-in. screen, using E-prime Psychology Software Tools Inc. version 2.0 software

(Schneider, Eschman, & Zuccolotto, 2002).

The stimuli of the IST were taken from the affective word list by Hermans and De

Houwer (1994), which lists valence (1 = very negative, 7 = very positive) and familiarity

(1 = not familiar at all, 7 = very familiar) ratings for 740 Dutch nouns and personality

traits. We selected 12 negative and 12 neutral nouns, and 12 negative and 12 neutral

personality traits, in such a way that stimuli did not differ in familiarity ratings or word

length, $t(47) < 1$, ns. All neutral words had an affective rating between 3.5 and 5, and a

familiarity rating of ≥ 3.4. All negative words had an affective rating of ≤ 3, and a

familiarity rating of ≥ 3.4. The negative words we selected were related to fear of failure

(e.g. exams) and relations (e.g. jealous), because these proved to be the 2 most frequent

themes of worry in the sample of students that participated (based on a pilot study with a

sample of undergraduates, $N = 310$). Words in white font, 7 mm high, were centrally

presented against a black background.

2.3. Procedure

All participants first completed four questionnaires: the PSWQ, the RRS, the

STAI, and the BDI-II. Based on the scores on the PSWQ and the RRS, participants were

invited to participate in the actual computer experiment. After completing the informed

consent form, the IST was carried out in individual testing cubicles of the psychology lab

of the VUB. Each participant ran through two task versions in a counterbalanced order. In

the *emotional task version* of the IST, participants were asked to keep a mental count of

the respective number of negative words and neutral words (without the use of external aids). In the *non-emotional task version* they were offered the same words, but they had to count nouns and personality traits.

Each block of trials started with a fixation cross (1500 ms), and contained 10 up to 15 words, presented one at a time. The number of words varied across blocks to ensure that individuals could not infer the number of words in the categories by means of subtraction. The presentation of the words was self-paced: by pushing the enter-button participants indicated that they had (mentally) added the target word to the correct category in their working memory. They were asked to perform this update as fast as possible without sacrificing accuracy. The time interval between the presentation of a word and the following 'enter'-response (reaction time) was recorded as dependent variable of task performance. After each 'enter'-response, the screen was cleared and the next word appeared, with a fixed response-stimulus interval of 200 ms. At the end of each block, participants were asked to report the number of words they mentally counted in each category, using the number pad of the keyboard. In both the emotional and non-emotional task version, participants completed 3 practice blocks followed by 12 experimental blocks.

Two types of count sequences were identified: a Switch (S) sequence, in which participants had to switch from one category to the other (e.g., a neutral word following a negative word), and a No Switch (NS) sequence, in which participants had to update the same category twice (e.g. a negative word following a negative word). Subtraction of response times of NS sequences from S sequences were taken as an index for the Internal Switching Cost (ISC; Garavan, 1998). In this way, higher index scores indicate higher

switch cost, which is a reflection of reduced cognitive control. The order of presentation of words within a block was randomly generated, creating the S and NS sequences described above.

3. Results

Through examination of the difference between RTs on S and NS sequences, we determined whether (1) worrying and (2) rumination were associated with an increased ISC. In order to minimize the influence of outliers, median RT scores were used. Accuracy was determined by the correct number of words in each category reported at the end of a block. On average 83% of the trials were correct or just +/- 1 away from the correct count. The exact distribution of the error rates is discussed below. To yield maximum power and to allow comparison with previous findings, all data, correct and incorrect, were included in the analyses (see De Lissnyder et al., 2012).

3.1. High-worriers versus low-worriers

3.1.1. Inclusion criteria. Based on their scores on the PSWQ, participants were divided into two groups: high-worriers (score > 57) and low-worriers (score < 38). High-worriers and low-worriers did not differ significantly with respect to age, $F(1, 44) = 0.33$, $p = .57$. However, there were disproportionally more females in the high-worriers group than in the low-worriers group, $\chi^2(1, 44) = 9.84$, $p = .002$ (see Table 1).

[Please, insert Table 1 here.]

3.1.2. ISC differences. For the analysis of RTs, we conducted a 2 x 2 x 2 mixed ANOVA with Switch (S sequences, NS sequences) and Condition (emotional task version, non-emotional task version) as within-subjects factors and Worry (high-worriers, low-worriers) as between-subjects factor. Analysis revealed a main effect of Switch, $F(1, 44) = 166.34$, $p < .001$, with RTs for NS sequences ($M = 1275$ ms, $SD = 285$) being lower than for S sequences ($M = 1589$ ms, $SD = 345$), indicating an overall switch cost. There was a main effect of Condition, $F(1, 44) = 27.40$, $p < .001$, revealing that performance was slower on the non-emotional task version ($M = 1540$ ms, $SD = 363$) as compared to the emotional task version ($M = 1351$ ms, $SD = 275$). A main between-subjects effect of Worry, $F(1, 44) = 4.09$, $p = .049$, indicated that high-worriers ($M = 1535$ ms, $SD = 325$) were generally slower than low-worriers ($M = 1363$ ms, $SD = 250$). More importantly, an interaction effect between Worry and Switch, $F(1, 44) = 8.54$, $p = .005$, indicated that the difference between S sequences and NS sequences, or the ISC, was greater for high-worriers ($M = 377$ ms, $SD = 198$) than for low-worriers ($M = 238$ ms, $SD = 119$) (see Figure 1a.). Other main/interaction effects were not significant.

3.1.3. Error rates. In order to investigate the distribution of the error rates, we reran the analysis with accuracy as a dependent variable in a 2 x 2 mixed ANOVA with Condition (emotional task version, non-emotional task version) as within-subjects factor and Worry (high-worriers, low-worriers) as between-subjects factor. Analysis revealed a significant difference in accuracy between the non-emotional task version ($M = 56\%$, $SD = 22\%$) and the emotional task version ($M = 48\%$, $SD = 16\%$), $F(1, 44) = 6.17$, $p = .017$. Other main/interaction effects were not significant.

3.1.4. Valence-specific ISC differences. To examine valence-specific effects, we calculated the ISC for sequences beginning with a negative word and sequences beginning with a neutral word, respectively named *ISC negative* and *ISC neutral*. We define *ISC negative* as the difference in RT between negative-neutral (S) and negative-negative (NS) sequences. *ISC neutral* is the difference in RT between neutral-negative (S) and neutral-neutral (NS) sequences. We then examined valence-specific differences within the emotional condition, using a 2 x 2 mixed ANOVA with Valence (ISC negative, ISC neutral) as within-subjects factor and Worry (high-worriers, low-worriers) as between-subjects factor. This was done in order to determine whether high-worriers exhibit a greater ISC than low-worriers when attention had to be diverted away from negative words, as opposed to neutral words. The analysis revealed a between-subjects effect of Worry, $F(1, 44) = 10.40$, $p = .002$, confirming that high-worriers ($M = 407$ ms, $SD = 259$) exhibited a greater ISC than low-worriers ($M = 219$ ms, $SD = 115$). Other main/interaction effects were not significant. There was no significant main effect of Valence or interaction effect of Valence and Worry. This means that there were no valence-specific differences in ISC for high-worriers versus low-worriers.

3.1.5. Additional analyses. Because of the interrelation between worrying and anxiety, we also determined whether the ANOVA results remained significant when we controlled for anxiety, as measured using the State Anxiety scale of the STAI. The same analysis as above (3.1.2.) with State Anxiety as covariate[1], indicated that the covariate State Anxiety was unrelated to the ISC, $F(1, 43) = 0.25$, $p = .944$, $r = .15$. The effect of

Worry on the ISC remained significant after controlling for the effect of State Anxiety, $F(1, 43) = 5.11$, $p = .029$.

Because of the correlation between scores on the PSWQ and RRS ($r = .55$, $p < .001$), we also conducted an analysis of covariance (ANCOVA) with Rumination as covariate[1]. The effect of Worry on the ISC remained significant after controlling for the effect of Rumination, $F(1, 43) = 4.22$, $p = .021$.

Given the unequal distribution of male and female students among the low-worriers group and high-worriers group, we conducted the same analysis as above (3.1.2.), but with Gender (male, female) as additional between-subjects factor. Results indicated that there was no interaction effect between Switch, Worry, and Gender, $F(1, 42) = 0.07$, $p = .790$. Importantly, the effect of Worry on the ISC remained significant after controlling for the effect of Gender, $F(1, 42) = 3.67$, $p = .050$.

Importantly, to determine the impact of personal relevance of worry themes, we added data from participants who worried about issues other than fear of failure and relationships, resulting in a total group of 63 participants ($N = 30$ low-worriers and $N = 33$ high-worriers). We performed the same analysis as above (3.1.2.), but with one additional between-subjects factor: Personal Relevance (personally relevant negative words, non-personally relevant negative words). The analysis revealed an interaction effect of the factors Switch, Worry, and Personal Relevance, $F(1, 59) = 10.98$, $p = .002$. Further within-group comparisons with a Bonferroni post hoc test, confirmed that the results described above were only present when the negative stimuli were personally relevant, $p < .05$. The ISC was not significantly greater for high-worriers compared to

low-worriers when the negative words in the IST were not personally relevant (see Figure 1).

[Please, insert Figure 1 here.]

3.2. High-ruminators versus low-ruminators

3.2.1. Inclusion criteria. Based on their RRS scores, participants were divided into two groups: high-ruminators (score > 56) and low-ruminators (score < 35). High-ruminators versus low-ruminators did not differ significantly with respect to age, $F(1, 38) = 0.32$, $p = .580$, or male/female ratio, $\chi^2(1, 38) = 3.74$, $p = .055$ (see Table 2).

[Please, insert Table 2 here.]

3.2.2. Results rumination groups. Results for high-ruminators were entirely similar to those for high-worriers; therefore we only summarize the most important results.

We conducted a 2 x 2 x 2 mixed ANOVA with Switch and Condition as within-subjects factors and Rumination as between-subjects factor. Analysis revealed an interaction effect between Rumination and Switch, $F(1, 38) = 7.62$, $p = .009$, indicating that the ISC was greater for high-ruminators ($M = 343$ ms, $SD = 194$) than for low-ruminators ($M = 206$ ms, $SD = 188$) (see Figure 1a.). When we controlled for Depression or Worry by entering them respectively as a covariate[1] and as an additional between subject variable[1] to the same analysis, the interaction Switch x Rumination remained

significant (respectively $F(1, 37) = 6.02$, $p = .019$ and $F(1, 37) = 7.69$, $p = .009$). When we added data from participants who worry about issues other than fear of failure and relationships and performed the same analysis with Personal Relevance as an additional between-subjects factor, analysis revealed an interaction effect of the factors Switch, Worry, and Personal Relevance, $F(1, 54) = 4.12$, $p = .047$. Further within-group comparisons with a Bonferroni post hoc test, confirmed that the interaction effect between Rumination and Switch was only present when the negative stimuli were personally relevant, $p < .05$ (see Figure 1).

4. Discussion

The present study investigated impaired cognitive control in worrying and rumination in relation to personal relevance of the stimuli. Using a new emotional version of the IST, we examined the ability of ruminators and worriers to switch between negative and neutral verbal stimuli in working memory, focusing on valence versus non-affective characteristics. The results of the current study indicated that persistent negative thought in general (both worrying and rumination) is associated with reduced cognitive control. Importantly, these cognitive control impairments were only found when the negative stimuli of the IST were personally relevant for participants. We will discuss these findings in more detail below.

In accordance with other studies (e.g. Davis & Nolen-Hoeksema, 2000; Donaldson et al., 2007; De Lissnyder et al., 2010) and theoretical notions (Koster, De Lissnyder, Derakshan, & De Raedt, 2011) this study confirms that reduced cognitive control is associated with rumination. Crucially, the results provide direct support for the

hypothesis that similar cognitive control impairments may play a role in worrying. To our knowledge, we are the first to demonstrate that worriers experience difficulties in updating and switching between internal representations in working memory. Our finding that worrying is associated with reduced cognitive control is therefore in line with the study by Brown (2009) indicating that worrying is negatively associated with cognitive control as displayed by inhibition impairments.

An unexpected finding was that cognitive control impairments associated with persistent negative thought were not valence-specific, as (1) the effects were similar when the participants focused on emotional versus non-emotional characteristics of the stimulus material and as (2) there were no differences between shifting from negative to neutral as opposed to from neutral to negative words. However, although the valence of stimuli was not relevant for the task in the non-emotional task version, the same neutral and negative nouns and personality traits were used in both conditions. Notwithstanding that the specific operations we measure are unrelated to valence, we cannot rule out the possibility that performance was influenced by the presence of negative words in both task versions. Nevertheless, the general effect we found is in accordance with two other studies using non-emotional material, indicating that rumination is associated with overall shifting impairments (Davis & Nolen-Hoeksema, 2000; Whitmer & Banich, 2007). It is also in line with a study by De Lissnyder et al. (2010), which showed that shifting impairments were not valence-specific when participants were confronted with emotional and non-emotional material. In contrast, a recent study by De Lissnyder et al. (2012) using the same IST with facial expressions as stimuli, did find rumination to be associated with valence-specific shifting impairments. At present, it thus remains unclear

under what conditions general versus valence-specific impairments are observed in relation to persistent negative cognition. Future research clarifying this issue is necessary.

Another important finding is that the ISC was only larger for ruminators and worriers when we solely included participants who indicated they worried about fear of failure and relationships. In other words, the negative stimuli in the IST had to be personally relevant to yield significant results. This is in agreement with other studies indicating that people react more strongly to personally relevant stimuli (Oathes et al., 2011, Siegle et al., 2003). Since there were no significant valence-specific effects it is unlikely that the general larger switch cost is due to a reduced ability to divert attention away from these personally relevant negative stimuli. A more likely explanation for this finding could be that the use of personally relevant negative words induced negative thought, especially in worriers and ruminators. According to some theorists, worrying (Eysenck & Calvo, 1992) and rumination (Watkins & Brown, 2002) deplete cognitive resources. Consequently, the negative thought-induction might explain reduced cognitive control in worriers and ruminators as they had less cognitive resources to switch between internal representations, resulting in an overall reduced cognitive control unrelated to the valence of information. However, this is only one of the possible interpretations of these results. Future longitudinal research should explore the causal relationship between persistent negative thought and cognitive control.

Importantly, the results of the present study show that cognitive control is related to persistent negative thinking, even after controlling for anxiety or depression. Moreover, there was no significant association between reduced cognitive control and mild symptoms of anxiety and depression, which is in line with some previous studies

showing a relationship between cognitive control and rumination, but not with depression (De Lissnyder et al., 2010; De Lissnyder et al., 2012; Whitmer & Banich, 2007). Yet, many other studies investigating the relationship between depression and cognitive control did find a negative correlation between these variables (e.g. Hertel, 2007; Joorman, 2004). Given that depressed individuals are generally characterized by high levels of rumination, the negative correlation between depression and cognitive control might be driven by the association between rumination and cognitive control. Possibly, the same goes for the relationship between worry, anxiety, and cognitive control. As far as we know, however, there are no other studies indicating that worry is a better predictor for reduced cognitive control than anxiety. On the contrary: a study by Verkuil, Brosschot, Putman, and Thayer (2009) indicated that worriers only show reduced cognitive control when they have high anxiety scores, and that they have enhanced cognitive control when anxiety is controlled for. In the current study, the limited number of participants with a high depression or anxiety score without a high rumination or worry score did not permit examining the exact relation between cognitive control and depression or anxiety. Future research could try to include more depressed or anxious participants without a tendency to perseverate in negative thoughts.

Although rumination and worrying are generally thought to be two distinct cognitive processes, we found that ruminators and worriers exhibited highly similar cognitive control impairments. The present findings seem to be in line with the idea that rumination and worrying are similar processes of persistent negative thought, potentially subserved by similar cognitive mechanisms. Nevertheless, the relation between cognitive control and worry remained significant when controlling for rumination, and vice versa.

This suggests that despite their overlapping mechanisms, rumination and worry have specific additional relationships to cognitive control that should be further specified in future research. If persistent thought in general is indeed the underlying vulnerability factor for developing both depression and/or anxiety disorders, this might be a possible explanation for the high co-morbidity between both disorders. Accordingly, it is crucial to further investigate the exact relationship between rumination, depression, worrying, and anxiety disorders, by studying why some individuals with a predisposition to perseverate in their thoughts become depressed and why others develop an anxiety disorder. In addition, if worrying and rumination are similar processes, it is advisable to use a more transdiagnostic approach to prevent depression and anxiety disorders by treating persistent negative thought. A better understanding of the reduced cognitive control mechanisms associated with persistent negative thought, and the conditions under which they occur, could be important for the development of therapeutic interventions that try to alter dysfunctional cognitive processing, such as cognitive bias modification. We believe it is important to note the fact that larger switch costs are not necessarily a disadvantage. In a study by Sheppes, Meiran, Gilboa-Schechtman, and Shahar (2008) healthy controls showed a larger switch cost to engage in negative thoughts when compared to dysphoric subjects, an effect that can be interpreted as a shield against negative thoughts.

There are some limitations to this study that should be tackled in future research. First, we found that worry and rumination, the cognitive features of respectively anxiety and depression, were primarily related to cognitive control impairments, rather than anxiety and depression themselves. But since we conducted this study in an

undergraduate sample, our results might underestimate the association between depression or anxiety and cognitive control impairments. Therefore it is important to verify whether our results can be generalized to a clinical sample. Second, one could argue that the conclusion that worrying and rumination are both associated with cognitive control impairments is due to the fact that we tested for this association in a sample that partially consisted of the same individuals. In this respect, it is noteworthy that despite the overlap (38.71%) there also were unique individuals in each sample. The results also remained similar when we controlled for rumination in the worry analysis, and vice versa. Third, a limitation of our version of the IST was that the non-emotional task version (categorizing words as noun or personality trait) was more difficult than the emotional task version (categorizing words as neutral or negative). Follow-up studies should use equally difficult tasks. Fourth, because the study did not include positive words, possible positive valence-specific effects were not investigated. Fifth, a potential limitation of including only extreme groups is that the results do not inform us about participants with an average rumination or worry score. Sixth, all the measures used are based on self-report. Future studies should compare self-report persistent negative thought measures and, for example, persistent negative thought inductions. Finally, it is important to note that the present correlational study does not allow us to draw any causal conclusions about the relationship between cognitive control and persistent negative thought.

In conclusion, we investigated the capacity of ruminators and worriers to switch between internal representations in working memory. The results of this study indicate that persistent negative thought is indeed associated with reduced cognitive control, but

only when the negative words used in the IST reflected personally relevant worry-themes for the participants. The current findings offer new insights into the underlying cognitive control mechanisms of persistent negative thought.

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Figure captions

Figure 1. ISC and SE as a function of Worry and Rumination for (a) only those participants for whom the stimuli are personally relevant ($N = 62$) and for (b) all participants ($N = 84$).

Footnotes

[1]We determined normality of the data using a Kolmogorov-Smirnov Test, kurtosis, and skewness measures. Results indicated that rumination and anxiety scores were normally distributed in the high- and low-worry groups. Depression scores were also normally distributed in the high- and low-rumination groups. However, worry-scores were not normally distributed in the high- and low-rumination groups. Therefore we entered Depression as a covariate and Worry as an extra dichotomous (divided based on a median-split) between subjects factor in the analyses.

Table 1

High-worriers and low-worriers that worry about fear of failure and relations

	female	male	age		PSWQ score	
	N	*N*	*M*	*SD*	*M*	*SD*
high-worriers	19	3	19.64	3.72	65.27	5.31
low-worriers	10	14	19.13	2.23	30.50	4.58
total	29	17	19.37	3.01	47.13	18.23

Table 2

High-ruminators and low-ruminators that worry about fear of failure and relations

	female	male	age		RRS score	
	N	*N*	*M*	*SD*	*M*	*SD*
high- ruminators	15	3	19.39	4.12	65.11	5.28
low-ruminators	12	10	18.82	2.17	32.41	1.99
total	27	13	19.08	3.17	47.13	16.90