

# Switching and Backward Inhibition in Major Depressive Disorder: The Role of Rumination

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Previous studies have demonstrated that individuals with major depressive disorder have difficulties switching attention from one task set to another. In the current study we examined whether ruminative thinking drives the switching deficits of depressed individuals. A secondary, more exploratory, goal of this study was to examine whether state rumination would impair depressed individuals' ability to activate a new task set, to inhibit a no longer relevant task set, or both. Participants underwent either a rumination induction or a distraction induction and then completed a backward inhibition task that measures general switching abilities and the ability to inhibit previous task sets. Although depression was not related to switching ability as a main effect, depressed individuals who were induced to ruminate exhibited poorer switching ability than did both depressed and control individuals who were distracted from ruminating and control participants who were induced to ruminate. These findings suggest that depressed individuals are characterized by switching deficits only if they are ruminating. Moreover, the finding that state rumination did not affect participants' ability to inhibit previous task sets suggests that state rumination primarily impairs noninhibitory task-switching processes. It is interesting that the opposite pattern of results was obtained for trait rumination, which was related to inhibitory deficits during switching, but not to generally poorer switching. Thus, state and trait rumination may be associated with dissociable cognitive deficits.

*Keywords:* rumination, major depressive disorder, switching, inhibition

Investigators have found that individuals diagnosed with major depressive disorder (MDD) have difficulties concentrating on information that is unrelated to their negative, self-relevant personal concerns (e.g., see Gotlib & Joormann, 2010). Researchers have posited that these difficulties are driven by underlying deficits in executive function, that is, in higher order cognitive control mechanisms that are involved in goal-oriented behavior (e.g., Purcell, Maruff, Kyrios, & Pantelis, 1997). Although investigators have shown that severely depressed inpatients exhibit widespread impairment in these control mechanisms (e.g., Harvey et al., 2004), researchers have generally failed to find deficits in executive function in less severely depressed individuals (Gotlib & Joormann, 2010).

The executive control mechanism that investigators have often found to be impaired in depressed individuals is set switching. When environmental contingencies change, individuals must direct attention away from currently active representations of ongoing

task demands and goal objectives (i.e., the attentional set) and attend to new sets. For example, in tasks such as the Wisconsin Card Sorting Task (WCST; Grant & Berg, 1948), participants must learn from negative feedback that a previously correct sorting is no longer correct, and they must instead start sorting stimuli according to a new rule. Consistent with findings of high levels of perseveration in individuals diagnosed with MDD (e.g., Waford & Lewine, 2010), a number of investigators have found that, despite the presence of negative feedback, depressed participants are more likely than are healthy controls to perseverate or continue sorting by no longer correct rules (e.g., Merriam, Thase, Haas, Keshavan, & Sweeney, 1999; Purcell et al., 1997), suggesting that the switching ability of depressed individuals is impaired. It is important to note, however, that tasks such as the WCST are not ideal measures of switching because perseveration may be caused by cognitive processes that are not directly involved in switching, such as processes that integrate negative feedback into the reward history of a stimulus. In this context, Lo and Allen (2011) assessed the performance of depressed individuals on a paradigm that explicitly cued participants to either switch task set or to repeat the same task. In this type of task-switching paradigm, switching ability is measured by assessing switch costs, or the additional time it takes for participants to respond on a switch trial (A at the end of a B-A task sequence) compared to a repeat trial (A at the end of an A-A task sequence). Lo and Allen found that depressed participants exhibited larger switch costs, or poorer switching ability, than did controls when switching between affective stimuli.

Although investigators have often found impaired switching in depressed individuals, it is important to note that several researchers have failed to find this effect (e.g., Martin, Oren, & Boone,

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1991; Meiran, Diamond, Toder, & Nemets, 2011). A number of factors, such as limited statistical power, may underlie these failures to replicate, but there is also reason to posit that ruminative thinking may affect switch costs. Investigators have argued that ruminative thinking can overload limited executive resources, thereby impairing task-relevant processing that depends on those resources (e.g., Philippot & Brutoux, 2008; Watkins & Brown, 2002). Given that task switching relies at least in part on executive resources (Monsell, 2003), it is possible that rumination impairs switching abilities. Consistent with this postulation, investigators have found that a self-reported tendency to ruminate is related to deficits during task switching (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; Whitmer & Banich, 2007).

It is not clear from studies examining a tendency to ruminate, however, whether ongoing (i.e., state) rumination in trait ruminators leads to switching deficits, whether switching deficits reflect a vulnerability factor for rumination, or whether a third unknown variable underlies the association between trait rumination and switching deficits. To examine whether state rumination causes switching deficits, Philippot and Brutoux (2008) induced rumination or distraction in dysphoric participants before examining their switching performance. Although the dysphoric participants exhibited poorer switching than did the nondysphoric participants, the rumination induction did not lead to switching deficits. It is possible that the use of a nonclinical sample is the reason for this null result; dysphoric individuals may be less influenced by the rumination induction and/or better at stopping ruminative thought than are clinically depressed individuals. It is also possible that the paradigm used by Philippot and Brutoux was insensitive to the effects of rumination because it did not allow for a trial-by-trial assessment of switching reaction times (RTs).

In the present study, we induced rumination or distraction in clinically depressed and never depressed participants and examined their subsequent performance in a task-switching paradigm that provides a trial-by-trial measure of RTs. We also attempted to control for participants' motivation because, as has been noted by previous investigators (e.g., Gotlib & Joormann, 2010), motivational deficits rather than difficulties in switching mechanisms per se may underlie depressed individuals' increased switch costs. To measure participants' level of motivation, we assessed the preparation effect (Monsell, 2003), that is, the decrease in switch costs that occurs when participants have extra time to prepare for an upcoming task switch. More motivated participants are expected to make more use of the extra preparation time to reduce the costs of switching, and thereby exhibit a larger preparation effect than do less motivated participants. We included a measure of the preparation effect in the current study to control for the possibility that the rumination induction impairs switching in depressed individuals primarily by decreasing motivation.

Although the primary aim of the present study was to examine whether rumination plays a causal role in depressed individuals' switching deficits, we also made a preliminary attempt to identify the precise switching-related mechanisms that may be affected by depression and rumination. Investigators have demonstrated that to switch to a new task set, individuals must deactivate the no longer relevant task set (see Koch, Gade, Schuch, & Philipp, 2010). Although this deactivation may occur in part through a passive decay of activity, an inhibitory process known as backward inhibition (BI) also has been posited to act

on the previous task set to accelerate the rate of deactivation and allow for a quicker and smoother transition to the new task set (e.g., Koch et al., 2010; Mayr & Keele, 2000). In addition to inhibitory processes, to switch task sets individuals must also use noninhibitory switching processes (NISPs) to activate mental representations of the new task demands (e.g., retrieve that task set from long-term memory, reconfigure working memory, etc.). Thus, it is not clear if inhibitory processes, NISPs, or both are impaired in clinically depressed individuals, especially in depressed individuals who are ruminating.

As a first step in examining this question, we assessed the performance of depressed participants on a modified task-switching paradigm (Mayr & Keele, 2000). This paradigm provides a general measure of switching ability (RTs of B-A > A-A sequences) that reflects both inhibitory and noninhibitory switching processes, as well as a measure of task set inhibition (Koch et al., 2010). When individuals switch from Task A to Task B, they are thought to inhibit Task A. Thus, when they must switch back to Task A (A-B-A sequence), it will take them longer to do so than when switching to a task set that was not as recently inhibited (C-B-A sequence) because extra time is needed to overcome the inhibition of task set A. This  $N - 2$  repetition cost is considered to be the only measure that isolates task set inhibition; indeed, investigators have demonstrated that noninhibitory accounts cannot explain  $N - 2$  repetition costs (see Koch et al., 2010). It is important to note that other paradigms also may measure inhibitory processes outside of the context of task switching; moreover, researchers have found evidence that state rumination impairs performance on such tasks (Philippot & Brutoux, 2008; Watkins & Brown, 2002). In this study, however, we examined only whether rumination impairs inhibitory mechanisms involved in switching. It is also important to note that although we can isolate BI from NISPs by comparing A-B-A to C-B-A trials, cognitive psychologists have yet to devise a way to do the opposite, that is, to isolate NISPs from BI. Therefore, it is difficult to demonstrate a deficit specifically in NISPs. Nevertheless, because switch costs reflect both NISPs and BI, we can infer that NISPs are impaired if individuals exhibit increased switch costs but are unaffected with respect to BI.

It is not clear if we should expect rumination in depressed individuals to affect BI, NISPs, or both. If ruminative thoughts overload limited executive resources, as suggested by Watkins and Brown (2002), then we should expect state rumination to impair any aspect of task performance that requires those resources. Because NISPs depend, at least in part, on executive resources (e.g., Monsell, 2003), they should be affected by the rumination induction. Moreover, the rumination induction should affect the NISPs of depressed participants more strongly than those of never depressed individuals because previous studies have demonstrated that rumination inductions have little effect on the thinking style of never depressed individuals (e.g., Lyubomirsky, Tucker, Caldwell, & Berg, 1999). In contrast to NISPs, it is unclear if BI requires executive resources (see Koch et al., 2010). Researchers have suggested instead that BI is an automatic process (Arbuthnott, 2008; Li & Dupuis, 2008; Mayr, 2001) that cannot be intentionally prevented (Mayr & Keele, 2000) or invoked (Hubner, Dreisbach, Haider, & Kluwe, 2003). If BI does not depend on executive resources, then it is unclear if rumination will impair BI.

Finally, it is important to point out that our manipulation of state rumination will not necessarily elicit the same type of cognitive deficits as investigators have found when examining trait rumination. On the one hand, it is possible that because trait ruminators are more likely than nonruminators to be in a naturally occurring state of rumination at the time they are assessed, elevated levels of state rumination underlie their cognitive deficits. On the other hand, a measure of trait rumination may also be sensitive to cognitive factors that make individuals susceptible to ruminative thinking when they become depressed. For example, an inability to inhibit no longer relevant information may lead individuals to be susceptible to rumination when they become depressed because thoughts are likely to remain in mind or to continue to repeat if they are not effectively deactivated or terminated. In this context, it is noteworthy that in a nondepressed sample, Whitmer and Banich (2007) found that trait rumination was related to BI deficits but not to switch costs. Moreover, Whitmer and Banich postulated that these deficits were not caused by state rumination, but instead, that inhibitory deficits lead individuals to be vulnerable to state rumination when they became depressed.

To examine this postulation in the current study, we administered the Ruminative Response Styles scale (RRS; Nolen-Hoeksema & Morrow, 1991) to participants to measure their tendency to ruminate and examined whether trait rumination was related to deficits in BI. If inhibitory deficits do function to increase individuals' vulnerability to rumination rather than representing a consequence of a ruminative state, then experimentally induced state rumination should not lead to inhibitory deficits, and further, trait rumination should be related to inhibitory deficits regardless of experimentally induced levels of state rumination. It is important to note that our experimental manipulation of state rumination means that trait ruminators in this study are not more likely to be in a ruminative state than are nonruminators. Therefore, naturally occurring states of rumination in trait ruminators cannot account for a relation found in this study between trait

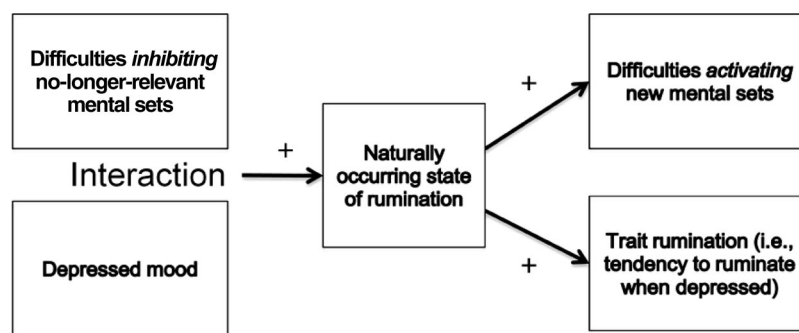
rumination and inhibitory deficits. Finally, as we noted above, state rumination may not affect BI; therefore, it is possible that we will find trait, but not state, rumination to be related to deficits in BI (see Figure 1 for an illustration of these postulated relations).

In sum, we predicted that depressed individuals who were induced to ruminate would exhibit larger switch costs than would both depressed individuals who were distracted from naturally occurring rumination and nondepressed control individuals who were induced to ruminate. We did not expect to find an effect of rumination in control participants. We included a measure of the preparation effect in our analyses to examine the effect of participants' level of motivation on switch costs. It was not clear if state rumination would affect BI, but we predicted, as has been found in previous studies, that trait rumination would be related to deficits in BI regardless of induction type or group status.

## Method

### Participants

There were 82 individuals (44 with MDD and 38 healthy controls) who participated in this study. Participants were solicited through advertisements posted in numerous locations (e.g., Internet bulletin boards, university kiosks, supermarkets, etc.). The Structured Clinical Interview for the *DSM-IV* (SCID; First, Spitzer, Gibbon, & Williams, 1995) was administered to all participants to assess current and lifetime diagnoses for anxiety, mood, psychotic, alcohol and substance use, somatoform, and eating disorders. The SCID has good reliability (e.g., Skre, Onstad, Torgersen, & Kringlen, 1991), and our team of trained interviewers has established excellent interrater reliability with this interview ( $k = .92$ ; e.g., Gotlib et al., 2004; Levens & Gotlib, 2010). Participants who met *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; American Psychiatric Association, 1994) criteria for current MDD were included in the depressed



*Figure 1.* The hypothesized relations among mood, mental set inhibition, mental set activation, state rumination, and trait rumination. The interaction of depressed mood and difficulties inhibiting no longer relevant mental sets is postulated to increase the frequency of naturally occurring states of rumination. A ruminative state is postulated to then lead to difficulties in activating new mental sets (a process that depends on executive control), but not in the ability to inhibit no longer relevant task sets (a process that appears to be automatic). Individuals who frequently experience states of naturally occurring rumination will report a higher tendency to ruminate (trait rumination), as measured with the Ruminative Response Styles (RRS) scale. It is important to note that in the present study, we manipulated participants' ruminative state instead of examining naturally occurring states of rumination to examine the causal effects of state rumination on switching. If the causal pathways postulated above are accurate, trait ruminators who are in a state of rumination will have difficulties both inhibiting a no longer relevant task set and activating a new set.

group, and participants with no current or past Axis I disorder were included in the control group. Participants also completed the 21-item Beck Depression Inventory–II (BDI–II; Beck, Steer, & Brown, 1996) to assess the severity of their depressive symptoms. The BDI–II has been found to have high reliability and validity (e.g., Beck et al., 1996). Participants were scheduled for a second session within 2 weeks of the interview session to complete the experimental task.

### Distraction and Rumination Inductions

**Induction tasks.** The rumination and distraction inductions were based on procedures developed by Nolen-Hoeksema and colleagues (Lyubomirsky & Nolen-Hoeksema, 1993, 1995; Morrow & Nolen-Hoeksema, 1990; Nolen-Hoeksema & Morrow, 1993) to alter the content of participants' thoughts. The rumination induction requires participants to engage in self-analysis about their current emotional state, whether that emotional state is desirable, and the implications of that mood state with respect to their ongoing progress toward their personal goals. Participants are not told specifically to focus on negative thoughts about themselves. Participants are asked to think about a series of statements such as, "Think about what your current feelings may mean" and "Think about whether you feel fulfilled." In contrast to the rumination induction, the distraction induction is designed to focus participants' thoughts externally and make it difficult for them to engage in rumination. Nolen-Hoeksema and colleagues (Nolen-Hoeksema & Morrow, 1993) used a distraction induction procedure that requires participants to focus their attention on external topics that are unrelated to themselves or their feelings, such as thinking about the expression on the face of the Mona Lisa. In pilot testing, however, we found that this distraction procedure was not effective in clinically depressed participants; indeed, researchers have used alternative distraction inductions with depressed samples (e.g., Donaldson & Lam, 2004; Joormann, Siemer, & Gotlib, 2007; Whitmer, Frank, & Gotlib, in press). Thus, in the current study, we used a distraction induction that we had implemented successfully with clinically depressed participants (e.g., Joormann et al., 2007). To induce distraction, we presented participants with a list of words and instructed them to use letters from that word to generate and write down two new words that start with that letter (e.g., *automobile*: *train* and *bus*). McFarland and Buehler (1998) reported that this task was easy but interesting enough to keep participants engaged. Both induction tasks took 8 min to complete.

**Mood questionnaire.** Participants completed a mood questionnaire before and after the induction. Using a 9-point Likert scale ranging from 1 (*not at all*) to 9 (*very much*), participants were asked to respond to two items: how "happy, positive, or good" and how "sad, negative, or bad" they felt.

### Trait Rumination

We measured trait rumination with short form of the RRS scale, using the 10 items suggested by Whitmer and Gotlib (2011). Items on this scale ask participants to rate how often they engage in ruminative thoughts when sad or depressed (e.g., "think about a recent situation wishing it had gone better"). Although some investigators have recommended examining separate subscales in the RRS (Treyner, Gonzalez, & Nolen-Hoeksema, 2003), other

researchers have found both the brooding and the reflection subscales to be related to deficits in BI (e.g., Whitmer & Banich, 2007). Further, recent research has indicated that these two subscales are not distinguishable in samples of clinically depressed participants such as that assessed in the present study (Whitmer & Gotlib, 2011). Therefore, we analyzed the 10-item scale and not the two subscales of the RRS scale.

### Measure of Backward Inhibition and Switch Costs

We used a backward inhibition task (Mayr & Keele, 2000) similar to that used by Whitmer and Banich (2007) to assess participants' task switching ability. In this task, participants identify the spatial location of a "deviant" object. Each stimulus display contains four rectangles arranged into a  $2 \times 2$  matrix. The rectangles can differ from each other on any one of three dimensions: size, orientation, and color. Shortly before the rectangles appear, a centrally presented cue (i.e., the word *size*, *orientation*, or *color*) identifies the dimension that participants should use to identify the rectangle that differs from the others. The position of the deviant rectangle is random. The cue remains on the screen until the participant makes a response on keys that have the same spatial position on the number pad as the rectangles have on the screen (i.e., keys "1," "2," "4," and "5"). Reaction times are used to compute separate measures of switch costs and backward inhibition. The task took approximately 10 minutes to complete.

To assess backward inhibition, or the inhibition of a previous task set, we compared performance on inhibitory trials (e.g., ABA) with performance on control trials (CBA). Participants generally inhibit task set A when switching to Task B, making it more difficult for them to return immediately to Task A (e.g., ABA), compared to a task set that was not inhibited as recently (CBA) because of the extra time needed to overcome inhibition of the representation of the prior task set (Mayr & Keele, 2000). It is important to note that because both control and inhibitory trials are preceded by two switches, the comparison of inhibitory and control trials yields a measure of inhibition that is not confounded by noninhibitory switching abilities (e.g., Mayr & Keele, 2000). Inhibitory and control trials were each presented on 22% of the total trials. If the rumination induction impairs backward inhibition, then participants who were induced to ruminate will have less inhibition to overcome and therefore, reduced time costs when reusing those representations.

Switch cost is measured by the additional time it takes to respond to noninhibitory "switch" trials (e.g., CBA and BBA trials) compared to "repeat" trials (e.g., AAA and BAA trials). Noninhibitory switch trials are an average of control trials (CBA; 22% of total trials) and unclassified switch trials (BBA; 23% of total trials); repeat trials occur 33% of the time. Switch costs will be larger if participants have difficulties inhibiting previous tasks sets or activating the mental representations of the task demands (Monsell, 2003). If the rumination induction leads to switching difficulties in depressed participants, then these participants should exhibit increased switch costs.

To examine the preparation effect, we manipulated the cue-stimulus interval (CSI) of the trials so that half of the trials had a CSI of 100 ms and half had a CSI of 900 ms. We kept the interstimulus interval (ISI) constant at 1,000 ms for both trial types to control for differences in decay of task set. Lower switch costs



at the longer than at the shorter CSI (i.e., a larger preparation effect) would suggest that participants used the longer CSI to prepare for the switch.

## Results

### Participant Demographic and Clinical Characteristics

One participant in the MDD-rumination group was eliminated for having a BDI-II score of 2, a value that was more than 2.5 standard deviations lower than the mean of the MDD group, and one participant in the control (CTL)-distraction group did not finish the task because of a computer malfunction. The analyses were conducted on a final sample of 22 participants in the MDD-rumination group, 21 in the MDD-distraction group, 20 in the CTL-rumination group, and 17 in the CTL-distraction group.

Demographic and clinical characteristics of the four groups of participants are presented in Table 1. A 2 (group: MDD vs. control)  $\times$  2 (condition: rumination vs. distraction) analysis of variance (ANOVA) conducted on age did not yield any significant effects, all  $F(1, 66) < 1$ . As expected, a two-way ANOVA conducted on BDI-II scores yielded a significant main effect of group,  $F(1, 66) = 237.25, p < .0001, \eta_p^2 = .782$ ; depressed participants had higher BDI-II scores than did healthy controls. Neither the main effect of condition,  $F(1, 66) = 0.056, p = .813, \eta_p^2 < .001$ , nor the interaction of group and condition,  $F(1, 57) = 1.02, p = .316, \eta_p^2 < .015$ , was significant. Finally, the distribution of gender was equivalent in the four groups,  $\chi^2(3) = .689, p = .876$ .

### Effect of Inductions on Mood

Positive and negative affect were strongly intercorrelated both before ( $r = -.66$ ) and after ( $r = -.67$ ) the induction procedure. Therefore, we reverse-scored the negative affect items and averaged the items measuring positive affect and negative affect to obtain a more reliable estimate of participants' mood. Higher scores on this measure reflect more positive and/or less negative affect. Scores on the measure of mood for the four groups of participants are presented in Table 1. A 2 (group: MDD vs. control)  $\times$  2 (condition: rumination vs. distraction)  $\times$  2 (time:

preinduction vs. postinduction) ANOVA yielded a significant main effect of group,  $F(1, 70) = 114.216, p < .0001, \eta_p^2 = .62$ , and a significant interaction of time and condition,  $F(1, 70) = 11.433, p = .001, \eta_p^2 = .14$ , that were qualified by a significant three-way interaction of group, condition, and time,  $F(1, 70) = 8.813, p < .004, \eta_p^2 = .112$ . A follow-up 2 (condition)  $\times$  2 (time) ANOVA conducted with participants in the MDD group yielded a significant interaction of condition and time,  $F(1, 36) = 15.69, p < .0001, \eta_p^2 = .303$ . Follow-up analyses revealed that depressed participants' mood became significantly more negative/less positive after the rumination induction  $t(19) = -2.46, p = .024$ , and significantly less negative/more positive after the distraction induction  $t(18) = 3.18, p = .005$ . In contrast, the two-way ANOVA conducted with participants in the control group did not yield a significant interaction of condition and time,  $F(1, 36) = .125, p = .725, \eta_p^2 = .004$ , indicating that the rumination and distraction inductions did not have significantly different effects on mood in the control group.

### Task-Switching Results

We excluded from analysis trials in which the reaction time was more than 3 standard deviations from each participant's mean RT and error trials. Following Mayr and Keele (2000), the two trials following an error were also excluded from analysis. Participants' mean accuracy was 97% and their mean RT was 1,438 ms. Reaction times and accuracy scores were subjected to a log transformation prior to data analysis to meet statistical assumptions regarding the homogeneity of variance.

**Effect of depression and state rumination on overall task performance.** To determine whether induced state rumination leads only to impaired task switching or also to generally poorer task performance, we first conducted a two-way (group: MDD vs. CTL; condition: rumination vs. distraction) ANOVA on the overall RT of the participants. This analysis yielded a marginally significant effect of group,  $F(1, 76) = 3.624, p = .061, \eta_p^2 = .046$ , indicating that the MDD group had somewhat slower RTs (3.18 log transformed ms) than did the CTL group (3.12 ms). Neither the main effect of condition,  $F(1, 76) = 2.129, p = .149, \eta_p^2 = .027$ , nor the interaction of condition and group,  $F(1, 76) = 1.9, p =$

Table 1  
Demographic and Clinical Characteristics of Participants

Characteristics	MDD rumination	MDD distraction	CTL rumination	CTL distraction
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
<i>N</i> (males)	22 (5)	21 (5)	20 (5)	17 (6)
Age	36.1 (11.5)	38.9 (11.6)	35.2 (12.0)	35.8 (10.5)
BDI-II	32.7 (11.24)	30.37 (9.3)	1.40 (1.7)	2.9 (3.2)
Mood (pre)	3.95 (1.4)	3.40 (1.3)	6.75 (1.3)	6.44 (1.6)
Mood (post)	3.16 (1.4)	4.32 (1.4)	6.97 (1.1)	6.78 (1.3)
No. taking antidepressants	8	13	0	0
Switch costs	.034 (.02)	.019 (.03)	.017 (.02)	.025 (.03)
Backward inhibition	.010 (.02)	.007 (.03)	.017 (.02)	.010 (.02)
RRS scale	2.66 (.78)	2.60 (.66)	1.63 (.70)	1.71 (.57)
RRS scale range	1.4–3.9	1.4–3.8	1–3	1–3.3

*Note.* MDD = participants diagnosed with major depressive disorder; CTL = healthy nondepressed control participants; BDI = Beck Depression Inventory-II; RRS = Ruminative Response Styles.

.172,  $\eta_p^2 = .024$ , was significant. A second two-way ANOVA conducted on overall accuracy yielded a significant effect of group,  $F(1, 76) = 6.207, p = .015, \eta_p^2 = .076$ , indicating that MDD participants were less accurate (96.2%) than were CTL participants (98.7%). Again, neither the main effect of condition,  $F(1, 76) = .031, p = .861, \eta_p^2 < .001$ , nor the interaction of condition and group,  $F(1, 76) = .055, p = .815, \eta_p^2 < .001$ , was significant. No other significant effects were found when examining accuracy, so we continue to discuss only analyses of RTs.

**Effect of depression and state rumination on switch costs and preparation effect.** Means and standard deviations for switch cost scores are presented in Table 1. A three-way ANOVA (group: MDD vs. CTL; condition: rumination vs. distraction; repeated over cue length: short vs. long) was conducted on the measure of switch costs (i.e., the difference in RT between switch and repeat trials; see Figure 2). The analysis did not yield significant main effects of group,  $F(1, 76) = 1.08, p = .302, \eta_p^2 = .014$ , or condition,  $F(1, 76) = .46, p = .498, \eta_p^2 = .006$ , but did yield a main effect of cue length,  $F(1, 76) = 4.283, p < .042, \eta_p^2 = .053$ . As expected, switch costs were smaller after longer (.019) than after shorter (.028) cue presentations, reflecting the predicted preparation effect. Cue length did not interact with group, condition, or the interaction of group and condition,  $ps > .63$ , indicating that these variables did not affect the size of the preparation effect. The ANOVA yielded a significant interaction only of group and condition,  $F(1, 76) = 4.53, p = .037, \eta_p^2 = .056$ ;<sup>1</sup> all other interactions were nonsignificant (all  $ps > .63$ ). Following up on this interaction, we found that the MDD-rumination group exhibited significantly larger switch costs (i.e., poorer switching) than did both the MDD-distraction group,  $F(1, 78) = 4.34, p = .04$ , and the CTL-rumination group,  $F(1, 78) = 5.49, p = .022$ ; as expected, the CTL-rumination group did not differ significantly from the CTL-distraction group,  $F(1, 78) = 1.06, p = .307$ .

**Effect of depression and state rumination on backward inhibition.** Means and standard deviations for scores on the measure of BI (increased RTs on A-B-A vs. C-B-A trials) are also presented in Table 1. A two-way (group: MDD vs. CTL; condition: rumination vs. distraction) ANOVA conducted on the measure of backward inhibition did not yield significant main effects of group,  $F(1, 76) = 0.869, p = .354, \eta_p^2 = .011$ , or condition,  $F(1, 76) = 1.113, p = .295, \eta_p^2 = .014$ , or a significant interaction of group and condition,  $F(1, 76) = 0.095, p = .759, \eta_p^2 = .001$ .

**Relation between trait rumination and task switching measures.** A regression analysis collapsed across condition and group (i.e., variables related to different levels of state rumination) indicated that trait rumination was related to decreased BI scores,  $t(67) = -2.0, \beta = -.236, p = .050$ , but not to increased switch costs,  $t(67) = 1.07, \beta = .130, p = .287$ , findings similar to those reported by Whitmer and Banich (2007). To examine whether trait rumination is related to BI even when the statistical model includes variables that account for variance related to depression status and induction type, we conducted a 2 (group: MDD vs. CTL) by 2 (condition: rumination vs. distraction) analysis of covariance (ANCOVA) on BI scores with scores on the RRS scale as a covariate. We also included BDI-II scores as a covariate to ensure that within-group differences in depressive severity or symptomatology did not account for the relation between the RRS scale and BI scores. We found RRS scale scores to be marginally related to lower BI scores,  $F(1, 53) = 3.52, p = .066, \eta_p^2 = .062$ . RRS scale

scores did not interact with any other variable or interaction in the model (i.e., group, condition, BDI-II, the interaction of group and condition, the interaction of group, condition, and BDI-II) to predict BI scores (all  $ps > .15$ ). Thus, the relation between trait rumination and BI scores does not seem to be substantially altered when we control for variables that are related to different levels of state rumination or depression.

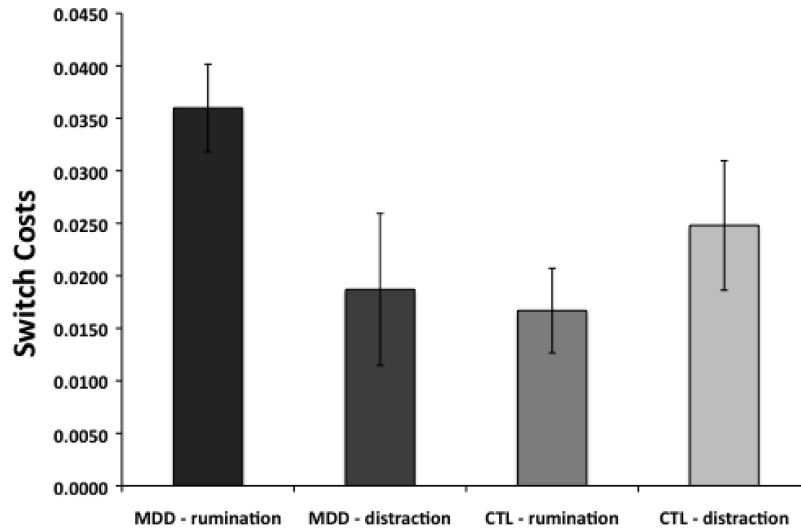
## Discussion

This study is the first to indicate that rumination impairs the ability of depressed individuals to switch between attentional sets. Inducing rumination led to larger switch costs in depressed individuals than in both depressed individuals who were distracted from naturally occurring rumination and control participants who were induced to ruminate. Rumination and distraction inductions did not affect switch costs in healthy controls. It is noteworthy that although depressed participants were overall slower and less accurate than were healthy controls, depression was not related to any switching-related measure independent of rumination. This failure to find a relation between depression and switching is striking given the relatively large sizes of the depressed and control groups (42 and 38, respectively). Thus, our findings suggest that deficits in task switching in moderately depressed individuals are strongly dependent on ruminative thinking. If ruminative thinking can be prevented or stopped, depressed individuals should exhibit stronger executive control function and, thereby, be better able to engage in adaptive behaviors.

Investigators have previously noted that it is difficult to distinguish between executive deficits and a lack of motivation in depressed participants (see Gotlib & Joormann, 2010). For example, if depressed individuals exerted as much effort as controls do, they might exhibit comparable performance in task-switching studies. It is unlikely, however, that a motivation account can explain the pattern of findings obtained in the present study. Inducing rumination in depressed participants did not lead to overall decrements in RT and accuracy, as would be expected if rumination had led to a general decrease in motivation in MDD. Furthermore, rumination did not affect the size of the preparation effect, that is, the reduction in switch cost when participants were given more time to prepare for an upcoming task switch, which would be expected if depressed participants who were induced to ruminate were simply less motivated than were participants who were induced to distract. Thus, the pattern of findings obtained in this study suggests that rumination leads to deficient switching ability but not to diminished motivation.

A secondary goal of the present study was to examine the effects of state rumination on task set inhibition and on noninhibitory switching processes. Given that ruminative thinking is posited to overload limited executive resources (Watkins & Brown, 2002) and that NISPs depend on executive resources, we expected state rumination to impair NISPs. In contrast, because BI is posited to be an automatic process that does not require executive resources,

<sup>1</sup> We reran this ANOVA with participants' medication status and difference in mood from before to after the induction as covariates. We again obtained a significant interaction of group and condition,  $F(1,67) = 4.1, p = .047, \eta_p^2 = .057$ , suggesting that these factors did not drive the interaction of group and condition in predicting switch costs.



*Figure 2.* Log transformed reaction times are presented on the y-axis. Switch costs refer to the longer reaction times obtained on switch trials (BA) compared to repeat trials (AA). Larger switch costs reflect poorer switching ability. To switch task sets, individuals both activate new task sets and inhibit previous task sets. The rumination induction, compared to the distraction induction, led to larger switch costs in the depressed group but not in the control group. Depression was not related to slower switching independent of rumination. MDD = major depressive disorder; CTL = control.

it was not clear that state rumination would cause BI deficits. In fact, we found in depressed participants that the rumination induction did not affect BI. Indeed, if anything, depressed participants who were induced to ruminate exhibited slightly stronger BI than did depressed participants who were distracted from ruminating.

It is interesting to note that in contrast to state rumination, trait rumination, as measured with the RRS scale, was related to BI deficits but not to increased switch costs. The relation between trait rumination and BI scores was found both when collapsing across, and when controlling for, variables that are related to different levels of state rumination and depression. These findings are similar to results reported by Whitmer and Banich (2007) and are generally consistent with their postulation that ongoing ruminations do not drive the relation between trait rumination and inhibitory deficits during task switching. Although these results are intriguing and suggest that BI deficits represent a vulnerability to rumination, it is nevertheless possible that a third, unmeasured, factor is driving this association.

In sum, we found that whereas trait rumination was related to BI deficits but not to increased switch costs, state rumination was related to increased switch costs but not to BI deficits. Given that switch costs reflect both BI and NISPs, we infer that state rumination primarily impairs NISPs instead of inhibitory processes during switching. This conclusion must be treated as tentative, however, given that we could not directly measure NISPs. Unfortunately, cognitive psychologists have not yet developed a measure that isolates NISPs from inhibitory processes; therefore, our ability to provide direct evidence that state rumination impairs NISPs is limited. It is also possible that state rumination would have impaired BI if we had used a more sensitive measure (i.e., if we had included more inhibitory and control trials in the BI task). If that were the case, however, state rumination should be only weakly related to BI deficits, or at least, less strongly related to BI deficits

than is trait rumination. Thus, we think that the present results indicate that state rumination is primarily related to NISPs and that trait rumination is primarily related to BI, suggesting that state and trait rumination are distinguishable constructs that are associated with distinct cognitive deficits.

We also should note that investigators have found in depressed and dysphoric samples that a rumination induction impairs performance on the Stroop and random number generation (RGN) tasks (Philippot & Brutoux, 2008; Watkins & Brown, 2002). Researchers have long theorized that performance on these tasks reflects, at least partially, the ability to inhibit or suppress prepotent responses (see Friedman & Miyake, 2004); therefore, the deficits exhibited by ruminating depressed individuals on these tasks may reflect inhibitory deficits. In this context, our failure to find an inhibitory deficit in ruminating depressed participants in the current study might be viewed as inconsistent with these previous findings. For several reasons, however, we do not think that this is the case. First, investigators have proposed accounts of these tasks that do not involve inhibitory processes (e.g., MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003); it is unclear, therefore, if these past studies did, in fact, demonstrate that rumination impairs inhibition. Second, even if deficits on the Stroop and RNG tasks do reflect impaired inhibitory processes, inhibition is not a unitary construct (e.g., Friedman & Miyake, 2004). Indeed, the measures used in the RNG and Stroop tasks are often thought to reflect prepotent response inhibition; in contrast, the BI measure used in the current study reflects the inhibition of a task set and not response inhibition (see Koch et al., 2010). Therefore, it is possible that rumination impairs response inhibition but not task set inhibition. Such a difference could arise if response inhibition relies more strongly on executive resources than does task set inhibition, given the postulated effect of rumination on executive resources. Clearly future

research is needed to examine more systematically and explicitly these theoretical postulations.

It is important to note here that, for two reasons, we did not use emotional stimuli in the current study. First, emotional stimuli may be more likely to trigger rumination than are neutral stimuli, which would decrease the effectiveness of our distraction induction and thereby, our ability to interpret any group differences. Second, the mechanisms involved in task switching (e.g., retrieving the new task set, reconfiguring the task set in working memory; inhibiting activation of the prior task set, etc.) are different from those involved in the processing of emotional salience (i.e., mechanisms that detect and draw attentional resources toward highly salient information). An overactive salience system could make it more difficult for individuals to switch away from negative information, not because switching mechanisms are impaired, but because the salience system is strongly directing their attention toward that information. This issue is of particular concern given that investigators have shown that both depressed mood and rumination are related to an overactive salience system (e.g., see Gotlib & Joormann, 2010). Thus, we would expect depressed ruminators to be slower than nonruminators and/or nondepressed individuals in switching away from negative information, even if the cognitive mechanisms involved in switching are unimpaired. Given that the goal of the current study was to examine the functioning of switching mechanisms and not of the salience system, we decided not to use emotional stimuli.

In this context, it is noteworthy that De Lissnyder et al. (2010) found that trait rumination in dysphoric participants was related not only to impaired BI as found in the current study and by Whitmer and Banich (2007), but to both impaired BI and larger switch costs. We speculate that De Lissnyder et al.'s use of emotional stimuli explains their unique finding that trait rumination was strongly related to impaired switch costs. Emotional stimuli could have triggered higher levels of state rumination, which would lead to increased switch costs. Moreover, as we noted above, trait ruminators have an overactive salience system (e.g., Joormann, Dkane, & Gotlib, 2006); therefore, it is also possible that anomalies in this system, and not in switching mechanisms, could underlie the difficulties of trait ruminators in switching away from emotionally negative information. Finally, given the positive relation between RRS scale scores and depression, our procedure of selecting samples of clinically depressed and never depressed participants may have resulted in a distribution of RRS scale scores that is more strongly bimodal than would be the case in samples of unselected participants. A potential limitation of this selection procedure is that it could have led to a stronger association between trait rumination and inhibitory deficits that would have been found in a randomly selected sample of participants.

In sum, the results of this study indicate that depressed individuals who are induced to ruminate exhibit switching difficulties, and that this deficit is not due to differences in motivation. Preliminary findings from this study also suggest that state rumination primarily impairs depressed individuals' ability to activate new task sets, rather than to inhibit previous task sets. Additional studies, however, are needed to replicate this latter finding and to examine whether state rumination impairs some types of inhibition-related processes, such as response inhibition, but not others.

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