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Sensitivity to reward and punishment in major depressive disorder: Effects of rumination and of single versus multiple experiences

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In the current study, we examined the postulation that rumination makes it difficult for depressed individuals to learn the exact probability that different stimuli will be associated with punishment. To do so, we induced rumination or distraction in depressed and never-depressed participants and then measured punishment and reward sensitivity with a probabilistic selection task. In this task, participants first learn the probability that different stimuli will be associated with reward and punishment. During a subsequent test phase in which novel combinations of stimuli are presented, participants' sensitivity to reward is tested by measuring their tendency to select the stimuli that were most highly rewarded during training, and their sensitivity to punishment is tested by measuring their tendency to not select the stimuli that were most highly punished during training. Compared with distraction, rumination led depressed participants to be less sensitive to the probability that stimuli will be associated with punishment and relatively less sensitive to punishment than reward. Never-depressed participants and depressed participants who were distracted from rumination were as sensitive to reward as they were to punishment. The effects of rumination on sensitivity to punishment may be a mechanism by which rumination can lead to maladaptive consequences.

Keywords: Rumination; Depression; Punishment; Reward; Learning.

Rumination about one's depressed mood and the causes and consequences of that mood is a common symptom of major depressive disorder (MDD; see Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Investigators have reported that depressed individuals engage in rumination because they believe that it is an inherently positive process that will lead to both insights about, and solutions to, their problems (Lyubomirsky & Nolen-Hoeksema, 1993; Papageorgiou & Wells, 2001, 2003; Watkins & Baracaia, 2001). Such positive beliefs about rumination, however, appear to be incorrect: rumination impairs insight and problem solving, leads to decreased tendency to implement

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solutions to problems, and exacerbates depressed mood (e.g., Lyubomirsky, Tucker, Caldwell, & Berg, 1999; see also Nolen-Hoeksema et al., 2008).

In recent years, investigators have attempted to identify cognitive processes that could exacerbate rumination and drive the maladaptive effects associated with rumination. For example, researchers have found evidence supporting the postulation that rumination overloads limited executive resources, making it difficult for depressed individuals to use executive control to stop their rumination and solve their problems (e.g., Philippot & Brutoux, 2008; Watkins & Brown, 2002). In the current study we examine whether ruminative thought also impairs punishment learning. If rumination impairs punishment learning, that would make it more difficult for depressed individuals to identify thoughts that lead to punishment and to identify which solutions to their problems are least likely to lead to punishment. Whitmer and Banich (2011) recently made a similar proposal but were unable to determine whether the deficits exhibited by ruminators in their study were driven by impaired executive function or by impaired punishment learning. Moreover, Whitmer and Banich did not explicitly manipulate rumination and, therefore, were also unable to examine the causal relation between rumination and punishment learning.

In the current study, we examined whether ruminative thinking makes it difficult for depressed individuals to learn the exact probability that different stimuli will be associated with punishment and to discriminate between stimuli that have slightly different punishment probabilities. Investigators have noted that rumination in depressed individuals amplifies the importance of negative information and occasional failures (i.e., punishment) because, for example, it links those failures to higher-order negative thoughts and beliefs (e.g., "I'm bad at this"; "I can never get anything right"; e.g., Lyubomirsky & Nolen-Hoeksema, 1995; Lyubomirsky et al., 1999; Watkins, 2008). We reasoned that if rumination leads depressed individuals to amplify the importance of occasional failures, then they should have difficulties differentiating between less important failures and more important failures. Thus, in a punishment learning paradigm, rumination may lead depressed individuals to think that a behaviour that is only occasionally associated with punishment (e.g., selecting stimulus A leads to punishment 40% of the time) is as "bad" as a behaviour that is often associated with punishment (e.g., selecting stimulus B leads to punishment 80% of the time).

In this context, it is noteworthy that investigators have demonstrated that healthy participants exhibit a trade-off between their sensitivity to single, recent instances of punishment or reward and their ability to gradually learn over multiple trials the exact probability that a stimulus will be punished or rewarded (e.g., Frank, Moustafa, Haughey, Curran, & Hutchison, 2007; Yechiam, Busemeyer, Stout, & Bechara, 2005). A sensitivity to single, recent experiences of punishment or reward is postulated to be mediated by working memory (WM); that is, a single experience is updated into WM so that it can guide subsequent behaviour. In contrast, the ability to gradually integrate reward and punishment outcomes over multiple experiences is not mediated by WM, but instead, by the neural system involved in habit learning. These two systems can work in opposition to each other because if individuals' expectation of reward or punishment is heavily influenced by single recent experiences, then their expectation that a stimulus will be rewarded or punished will vary considerably from instance to instance. This variability will lead the habit system to make "blurry" estimates of reward and punishment (i.e., estimates with wider confidence intervals around them). These blurry estimates, in turn, will make it difficult for individuals to distinguish between stimuli of slightly different reward and punishment probabilities. In contrast, individuals who are less influenced by single, recent experiences of reward or punishment will have more stable expectations of the reward and punishment values of stimuli from instance to instance, allowing their habit system to gradually develop more precise estimates (i.e., narrower confidence intervals) of reward and punishment probability.

This past research is consistent with our postulation that rumination will make it difficult for depressed individuals to distinguish among stimuli of slightly different punishment probabilities. Rumination should amplify the attention of depressed individuals to single, recent instances of punishment (i.e., negative feedback is likely to be updated into WM), thereby impairing the ability of their habit learning system to gradually generate precise estimates of the probability that stimuli will be punished. In turn, less clear estimates of punishment probability will make it more difficult for depressed ruminators to distinguish among stimuli with different probabilities of being punished. Interestingly, this research also suggests that rumination will have the opposite effect on reward learning. Rumination leads depressed individuals to undervalue or pay less attention to positive information (e.g., Lyubomirsky & Nolen-Hoeksema, 1995), which in the context of this past work, suggests that they are unlikely to update single, recent experiences of reward into WM. In turn, decreased focus on recent reward will allow the reward expectations of depressed individuals to be more stable across trials and enable their habit learning system to gradually develop more precise estimates of reward probabilities. Thus, rumination may actually make it easier for depressed individuals to distinguish among stimuli of slightly different reward probabilities than among stimuli of slightly different punishment probabilities.

To examine whether depressive rumination leads to less precise estimates of punishment probability and more precise estimates of reward probability, we induced rumination or distraction in clinically depressed and never-depressed participants and then tested their performance on a probabilistic selection task (Frank, Seeberger, & O'Reilly, 2004). In the initial training phase of this task, participants are presented with pairs of stimuli and are required to select the stimulus from each pair that is most likely to be rewarded and least likely to be punished. In a subsequent "test" phase in which no feedback is provided, novel pairs of task stimuli are presented. If participants are sensitive to the reward probabilities of stimuli, they will be able consistently to select or "approach" the stimuli that were most highly rewarded during training; similarly, if they are sensitive to the punishment probabilities of stimuli, they will be able consistently to *not* select or "avoid" the stimuli that were most highly punished during training. We predicted that the rumination induction, particularly in depressed individuals, would lead to decreased sensitivity to the punishment probabilities of stimuli and to relatively better reward learning than punishment learning.

METHODS

Participants

Eighty-three individuals (44 with MDD and 39 healthy controls) 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 inter-rater reliability with this interview ($\kappa = .92$; e.g., Gotlib et al., 2004; Levens & Gotlib, 2010). Participants who met DSM-IV criteria for current MDD were included in the depressed group, and participants with no current or past Axis I disorder were included in the control group. All participants also completed the 21-item Beck Depression Inventory–II (BDI; Beck, Steer, & Brown, 1996), assessing the severity of their depressive symptoms. Over several decades the BDI has been found to have high reliability and validity (e.g., Beck et al., 1996). Participants were scheduled for a second session within two weeks 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 to alter the content of participants' thoughts (Lyubomirsky & Nolen-Hoeksema, 1993, 1995; Morrow & Nolen-Hoeksema, 1990; Nolen-Hoeksema & Morrow, 1993). The rumination induction requires participants to engage in self-analysis about their current emotional state, whether that emotional state is desirable, and what the implications of that mood state are with respect to their ongoing progress towards their personal goals. Participants are not told specifically to focus on negative thoughts about themselves. Participants were 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 to make it difficult for them to engage in rumination. Nolen-Hoeksema and her colleagues 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 (Nolen-Hoeksema & Morrow, 1993). 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). Thus, in the current study, we used a distraction induction that we have implemented successfully with clinically depressed participants (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 Beuhler (1998) reported that this task was easy but interesting enough to keep participants engaged. Both induction tasks took eight minutes to complete.

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

Probabilistic Selection Task

The Probabilistic Selection Task (Frank et al., 2004) begins with a forced-choice training phase followed by a test phase (see Figure 1). During training, participants are presented with three stimulus pairs (AB, CD, and EF). Each stimulus is a different hiragana character (Japanese syllabary) and is associated with different reward probabilities (A: 80%; B: 20%; C: 70%; D: 30%; E: 60%; F: 40%). The hiragana characters that correspond to different reward probabilities were randomly varied among subjects. The position of each character on the left or right side of the screen was randomly varied across trials (e.g., AB or BA). Participants were required to make a button press (left or right arrow) to select a stimulus upon the presentation of each pair (e.g., select stimulus A when they see the AB pair). Reward was signalled if the participants' choice was followed by the word "correct", and punishment was signalled if the participants' choice was followed by the word "incorrect". Participants were instructed to start the training by picking either one of the two stimuli, and then to consistently pick the stimulus from each pair that they believed was rewarded more frequently. Participants were trained until they reached criterion on all pairs, with a different criterion being used for each stimulus pair (65% A in AB; 60% C in CD; 50% E in EF; the more difficult the discrimination, the easier the criterion). Criterion was evaluated after every block of 60 trials and, consistent with Chase et al. (2010), all participants were given a maximum of 10 blocks to reach criterion.

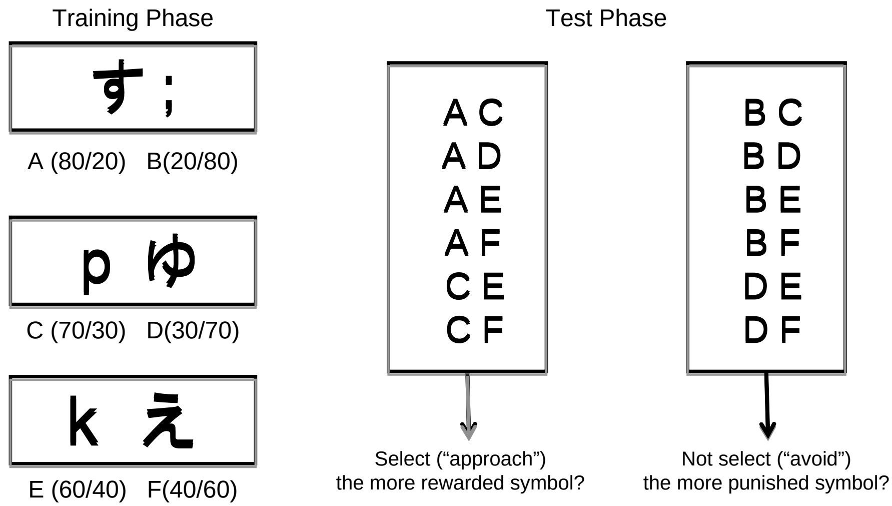

Figure 1. *Description of task (modelled after Frank et al., 2007). In the training phase, participants learn to select the more highly rewarded stimulus in each of the three pairs of stimuli. Stimuli (presented in the form of Japanese syllabary) are each associated with different probabilities of being rewarded (i.e., "correct!") or punished (i.e., "wrong!") upon selection. For example, stimulus A is rewarded 80% of the time that it is selected and punished 20% of the time. After training, participants are tested with novel combinations of stimuli. They can exhibit good reward learning, that is, the ability to discriminate among stimuli of slightly different reward probabilities, by always selecting or "approaching" the stimulus that was more highly rewarded during training. Similarly, they can exhibit good punishment learning, that is, the ability to discriminate among stimuli of slightly different punishment probabilities, by always not selecting or "avoiding" the stimulus that was more highly punished during training.*

In a test phase following the training, we examined how well participants had integrated reward and punishment outcomes across all trials in the training to be able to generate precise estimates of the reward and punishment probabilities of the stimuli. In this phase, all possible combinations of stimulus pairs (AE, BC, etc.) were each presented four times. Participants were instructed to "follow their gut" when selecting the stimulus in each pair they thought was most likely to be correct. It is important to note that no feedback was given during the test phase, so no new learning should occur during that phase. Thus, the test phase was used to assess learning that occurred during the training phase. Participants' learning of reward probabilities was measured by their ability to select or "approach" the more highly rewarded stimuli in all novel combinations that included these stimuli (e.g., choose A in AC, AD, AE, and AF or choose C in CE and CF). Similarly, participants' learning of punishment probabilities was measured by their ability to not select or "avoid" the more highly punished stimulus in all novel combinations when paired with the same alternative stimuli (e.g., avoid B in BC, BD, BE, BF or avoid D in DE DF). We should note here that we use the terms "approach" and "avoid" only with respect to whether participants selected the stimulus that had been rewarded the most in training or did not select the stimulus that had been punished the most during training, respectively. Because there was no feedback given during the test phase, participants did not directly avoid a punishment or directly approach a reward.

Procedure

For the experimental session, patients and controls were randomly assigned to the distraction or the rumination condition. Participants first rated their mood, then completed the rumination/distraction induction task, then rated their mood a second time, and finally completed the probabilistic selection task.

RESULTS

Participant demographic and clinical characteristics

Initially, 22 MDD and 19 control participants were assigned to the rumination induction condition, and 22 MDD and 20 control participants were assigned to the distraction condition. Three participants in the MDD-rumination group and two participants in the MDD-distraction group stopped the task before they were done (potentially because of frustration). An additional two participants in the MDD-rumination group, four participants in the MDD-distraction group, two participants in the control-rumination group, and four participants in the control-distraction group did not reach training criteria on the AB, CD, and EF pairs within the 10 allotted blocks and, consequently, were removed from analyses. It is important to note that other investigators have found similar attrition rates with this task (e.g., Chase et al., 2010; Frank et al., 2004; Waltz, Frank, Wiecki, & Gold, 2007). Finally, four participants (one in each of the groups) were removed from analyses because they exhibited an anomalous change in mood following the induction procedure (>3 standard deviations from their group's mean). Thus, analyses were conducted on a final sample of 16 participants in the MDD-rumination group and 15 participants in each of the other three groups.

Demographic and clinical characteristics of the 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 Fs(1, 57) < 1. A 2 $\times$ 2 ANOVA conducted on BDI scores yielded a significant main effect of Group, $F(1, 57) = 194.835$, $p < .0001$, $\eta_p^2 = .774$: as expected, depressed participants had higher BDI scores than did non-depressed controls. Neither the main effect of Condition, $F(1, 57) = 0.001$, $p = .979$, $\eta_p^2 < .0001$, nor the interaction of Group and Condition, $F(1, 57) = 1.101$, $p = .298$, $\eta_p^2 < .019$, was significant. Finally, the distribution of gender was equivalent in the four groups, $\chi^2(3) = 0.294$, $p = .961$.

The effects of the rumination and distraction induction on mood

Across all participants, positive and negative affect were strongly intercorrelated both before ($r = .72$) and after ($r = .52$) the induction procedure, and also when examining change in mood from before to after the induction ($r = .54$). Therefore, we combined the items measuring positive affect and negative affect in order to obtain a more reliable estimate of participants' mood. We reverse-scored the negative affect item and used the average score of the positive and negative affect items as a measure of mood, with higher scores reflecting 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

Table 1. *Demographic and clinical characteristics of participants*

	MDD rumination	*MDD distraction*	*CTL rumination*	*CTL distraction*
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
N (males)	16 (5)	15 (5)	15 (5)	15 (6)
Age	35.9 (11.5)	39 (13.2)	38.9 (10.4)	35.5 (15.0)
BDI	26.37 (8.8)	28.27 (9.2)	3.67 (4.1)	1.87 (2.8)
Mood (pre)	4.62 (1.9)	4.74 (1.1)	7.4 (1.4)	7.43 (1.3)
Mood (post)	3.44 (1.9)	5.13 (0.87)	7.0 (1.5)	7.5 (1.2)
Number taking antidepressants	9	4	0	0

Notes: MDD = participants diagnosed with major depressive disorder; CTL = healthy non-depressed control participants; BDI = Beck Depression Inventory–II. Standard deviations are in parentheses.

vs. distraction) × 2 (Time: pre-induction vs. post-induction) ANOVA conducted on this measure yielded significant main effects of Group, $F(1, 57) = 64.446$, $p < .0001$, $\eta_p^2 = .531$, and Time, $F(1, 57) = 7.261$, $p = .009$, $\eta_p^2 = .113$, which were qualified by a significant three-way interaction of Group, Condition, and Time, $F(1, 57) = 7.261$, $p < .009$, $\eta_p^2 = .113$. A follow-up 2 (Group) × 2 (Time) ANOVA conducted with participants in the rumination condition yielded a significant interaction of group and time, $F(1, 29) = 5.792$, $p < .023$, $\eta_p^2 = .166$, indicating that the rumination induction led to lower mood scores (i.e., less positive and/or more negative affect) in depressed individuals than in controls. A similar 2 (Group) × 2 (Time) ANOVA conducted with participants in the distraction condition yielded only a significant main effect of Group, $F(1, 28) = 42.227$, $p < .0001$, $\eta_p^2 = .601$; neither the main effect of Condition, $F(1, 28) = 3.379$, $p = .077$, $\eta_p^2 = .108$, nor the interaction of Group and Time, $F(1, 28) = 1.724$, $p = .20$, $\eta_p^2 = .058$, was significant, indicating that the distraction induction did not differentially affect depressed and non-depressed participants' mood.

Trials to criterion

A 2 (Group: MDD vs. control) × 2 (Condition: rumination vs. distraction) ANOVA conducted on the number of trials taken by participants to reach criterion did not yield significant main effects, all Fs$(1, 56) < 1$, or a significant interaction of Learning Type and Group, $F(1, 56) = 0.013$, $p = .911$, $\eta_p^2 < .001$.

Test phase results

A 2 (Group: MDD vs. control) × 2 (Condition: rumination vs. distraction) × 2 (Learning Type: reward vs. punishment) analysis of covariance (ANCOVA) was conducted on accuracy during the test phase (Reward Learning: mean accuracy on A vs. C, D, E, F, and C vs. E, F trials; Punishment Learning: mean accuracy on B vs. C, D, E, F, and D vs. E, F trials), assessing how well participants integrated reward and punishment outcomes, respectively, during training. The difference in mood scores from before to after the rumination or distraction induction was included as a covariate in order to ensure that significant effects were not due simply to different effects of the two induction procedures on participants' mood but, instead, reflected changes in cognitive processing that were directly related to changes in rumination (i.e., increased ruminative thinking about one's problems and feelings).[1] This analysis did not yield significant main effects, all Fs$(1, 56) < 1$, or a significant interaction of Learning Type and Group, $F(1, 56) = 1.14$, $p = .29$, $\eta_p^2 = .02$. It did yield a significant interaction of Learning Type and Condition, $F(1, 56) = 12.3$, $p < .01$, $\eta_p^2 = .18$, which was qualified by a significant three-way interaction of Group, Condition, and Learning Type, $F(1, 56) = 5.643$, $p < .021$, $\eta_p^2 = .092$.

To examine this three-way interaction, we conducted separate 2 × 2 (Group by Condition) ANCOVAs for reward and punishment learning (see Figure 2). The ANCOVA conducted on punishment learning yielded a significant interaction of Group and Condition, $F(1, 56) = 5.43$, $p = .023$, $\eta_p^2 = .088$. Simple effects analyses indicated that whereas in the MDD group the rumination induction led to significantly less sensitivity to punishment probabilities than did the distraction induction, $F(1, 56) = 7.93$, $p = .007$, $\eta_p^2 = .124$, induction type did not significantly affect sensitivity to punishment in the control group, $F(1, 56) = 0.001$, $p = .961$, $\eta_p^2 < .001$. The ANCOVA conducted on reward sensitivity did not yield a significant interaction of Group and Condition, $F(1, 56) = 1.03$, $p = .314$, $\eta_p^2 = .018$, but did yield a significant main effect of Condition, $F(1, 56) = 10.11$, $p < .002$,

[1] The ANOVAs conducted without mood as a covariate yielded a similar pattern of results as those obtained with the ANCOVAs; however, without covarying mood, some results were slightly weaker and some were slightly stronger. Because we wanted to examine the effects of ruminative thinking (not the effects of mood change) on punishment learning, we present the analyses controlling for possible mood change.

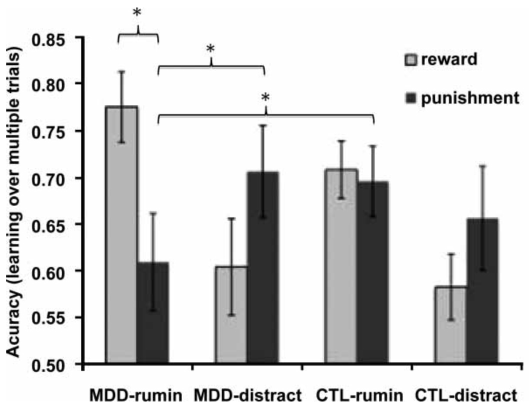

Figure 2. *Learning of reward and punishment during the test phase. Error bars indicate standard error. Asterisks indicate significant simple effects. MDD = participants diagnosed with major depressed disorder; CTL = healthy non-depressed control participants; Rumin = individuals who received the rumination induction; Distract = individuals who received the distraction induction; Y-axis: accuracy = ability to approach rewarded stimuli or to avoid punished stimuli.*

$\eta_p^2 = 153$; the rumination induction led to greater sensitivity to reward probabilities than did the distraction induction.

To examine whether relative sensitivities to reward versus punishment were significantly different in the groups, we also broke down the significant three-way interaction by conducting separate 2×2 (Group by Learning Type) ANCOVAs for the rumination and distraction conditions. The ANCOVA conducted for the rumination condition yielded a significant interaction of Group and Learning Type, $F(1, 56) = 4.17$, $p < .05$, $\eta_p^2 = .070$. Simple effects analyses indicated that the rumination induction led to significantly less sensitivity to punishment than reward probabilities in the MDD group, $F(1, 56) = 5.58$, $p < .05$, $\eta_p^2 = .091$, but not to significant differences in sensitivity to reward and punishment in the control group, $F(1, 56) = 0.06$, *ns*, $\eta_p^2 < .001$. The rumination induction led the MDD participants to be significantly poorer at punishment learning than were the control participants, $F(1, 56) = 4.14$, $p < .05$, $\eta_p^2 = .07$; the two groups did not differ significantly with respect to reward learning, $F(1, 56) = 0.72$, *ns*, $\eta_p^2 = .013$. The ANCOVA conducted for the distraction condition did not yield a significant interaction of group and learning type, $F(1, 56) = 0.18$, *ns*, $\eta_p^2 = .023$. The results of these analyses suggest that if MDD participants are not ruminating, they do not differ significantly from the control participants in their sensitivity to the probabilities of being rewarded versus punished.

DISCUSSION

This study is the first to find clear evidence that rumination in clinically depressed individuals leads to a decreased sensitivity to punishment. Specifically, we found that, compared to distraction, rumination led depressed participants to be poorer at learning the exact probability that a stimulus will be associated with punishment, as demonstrated by a decreased ability to avoid or not select during the test phase the stimuli that had been most highly punished during the training phase. For example, depressed individuals who had been induced to ruminate were more likely than were depressed individuals who had been distracted from ruminating to select a stimulus that had been punished 80% of the time during training as often as they selected a stimulus that had been punished only 70% of the time during training. Interestingly, this finding suggests that a period of rumination will make it more difficult for depressed individuals to avoid the "greater of two evils". This is particularly important given that depressed individuals often face difficult problems that are unlikely to offer opportunities for reward, but instead, courses of action with more or less negative consequences. If rumination makes it difficult for depressed individuals to identify and select the least negative course of action, it may lead to a reduced likelihood that they will implement any course of action. Thus, the effects of rumination on sensitivity to punishment probabilities may explain why Lyubomirsky et al. (1999) found that a rumination induction decreases the likelihood that dysphoric individuals will take steps towards resolving their problems.

Depressed individuals who were induced to ruminate exhibited relatively higher sensitivity to reward than to punishment. Interestingly, all other groups of participants exhibited equal sensitivities to probabilities of punishment and reward. This finding is consistent with previous results of computational models and experimental studies demonstrating that healthy individuals exhibit equivalent sensitivities to probabilities of punishment and reward (e.g., see Frank et al., 2004), and suggests that rumination has a negative effect on depressed individuals' sensitivity to punishment probabilities, but not to reward probabilities. Indeed, the results suggest that rumination leads to *higher* sensitivity to reward probabilities in depression. Unfortunately, because depressed individuals are not likely to place themselves in situations that offer reward or to have thoughts that lead to reward, the effect of rumination on reward sensitivity may have few beneficial consequences outside of the laboratory. Nonetheless, if investigators can demonstrate that depressive rumination does lead to better reward learning in a variety of contexts, this unexpected benefit of rumination may be of therapeutic use.

It is noteworthy that while previous investigators have found that rumination impairs depressed individuals' performance on tasks that require executive function (e.g., Watkins & Brown, 2002), sensitivity to reward and punishment probabilities in the probabilistic selection task is posited to rely on a habit learning system and not on executive function (see Frank et al., 2007). Thus, the current results suggest that rumination affects cognitive mechanisms involved not only in executive function, but also in habit learning. Indeed, the effect of rumination on the habit learning system may explain why ruminative thoughts are likely to become automatic, passive, and habitual.

Previous investigators have found that MDD is associated with aberrant reward and punishment learning (e.g., Cella, Dymond, & Cooper, 2010; Eshel & Roiser, 2010; Must et al., 2006; Steele, Kumar, & Ebmeier, 2007). This study is the first to manipulate the degree to which depressed participants engage in rumination during reward and punishment learning. In this context, it is noteworthy that, independent of rumination, MDD was not associated with most measures of reward and punishment learning. It is possible, however, that because depressed participants will often ruminate without being induced to do so, naturally occurring levels of rumination may underlie some of the previously reported relations between MDD and the processing of reward and punishment. It is also possible that low levels of rumination in depressed participants may account for some of the null results that have been previously reported (e.g., Purcell, Maruff, Kyrios, & Pantelis, 1997; Shah, O'Carroll, Rogers, Moffoot, & Ebmeier, 1999). For example, Chase et al. (2010) did not find association between MDD and reward-punishment learning using the same probabilistic selection task that was used in this study. If only a few of the depressed participants in that study were in a ruminative state, however, it is not surprising that they did not find evidence of aberrant depression-associated reward-punishment learning. In fact, in the present study we found that depressed individuals exhibited different sensitivities to reward and punishment learning only if they had been induced to ruminate. Depressed individuals who had been induced to distract themselves from ruminating did not differ from non-depressed controls in their relative ability to avoid punishment versus to approach reward.

In sum, the current findings suggest that rumination affects depressed individuals' sensitivity to probabilities of punishment and reward. The ability of rumination to decrease sensitivity to punishment probabilities may make it more difficult for depressed individuals to avoid the "greater of two evils" and, therefore, to identify better solutions to their problems and engage in less maladaptive forms of behaviour.

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