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Depressive Symptoms Enhance Loss-Minimization, but Attenuate Gain-Maximization in History-Dependent Decision-Making

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Abstract

Individuals with depressive symptoms typically show deficits in decision-making. However, most work has emphasized decision-making under gain-maximization conditions. A gain-maximization framework may undermine decision-making when depressive symptoms are present because depressives are generally more sensitive to losses than gains. The present study examined decision making in a non-clinical sample of depressive and non-depressive individuals under gain-maximization or loss-minimization conditions using a task for which the currently available rewards depend upon participants' previous history of choices. As predicted, we found a cross over interaction whereby depressive individuals were superior to non-depressive individuals under loss-minimization conditions, but were inferior to non-depressive individuals under gain-maximization conditions. In addition, we found that loss-minimization performance was superior to gain-maximization performance for depressive individuals, but that gain-maximization performance was superior to loss-minimization performance for non-depressive individuals. These results suggest that decision making deficits observed when depressive symptoms are present may be attenuated when decisions involve minimizing losses rather than maximizing gains.

Keywords

depressive symptoms; gains; losses; reward; punishment; decision making; choice

1. Introduction

Depression is a common, recurrent, and impairing condition that predicts future suicide attempts, interpersonal problems, unemployment, and substance abuse (Kessler et al., 2003;

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¹All analyses reported below were also examined with age and gender as a factor. In no case did either measure yield a significant main effect, nor did they interact with any other factor.

²Participants received a flat-rate monetary compensation of \$10 that was not dependent upon performance in the task. We have conducted a number of studies in our laboratory that used flat-rate compensation and others that used performance-driven compensation. Although no systematic comparisons have been made, we find very few differences in performance as a function of the type of monetary compensation. It is worth mentioning that this also holds in the depression literature with studies using flat-rate or performance-based compensation showing similar patterns of performance.

Kessler & Walters, 1998). According to the World Health Organization, 121 million people currently suffer from depression and many more have elevated depressive symptoms. Furthermore, adults with elevated depressive symptoms, even in the absence of Major Depressive Disorder, have worse physical, social, and role functioning compared to a demographically similar group without a chronic health condition. Indeed, well-being and psychosocial functioning of individuals with high depressive symptoms are comparable to people with major chronic medical conditions, such as hypertension, diabetes, and arthritis (Wells et al., 1989). Thus, it is important to examine how depressive symptoms affect basic cognitive processes due to the pervasiveness of these symptoms in the population.

Cognitive processes such as decision-making appear to be strongly affected by the presence of depressive symptoms. Empirically, depressive symptoms have been shown to affect problem-solving (Elderkin-Thompson, Mintz, Haroon, Lavretsky, & Kumar, 2006), planning (Rogers et al., 2004), cognitive flexibility (Butters et al., 2004) and decision-making (Clark, Chamberlain, & Sahakian, 2009; Gradin et al., 2011; Murphy et al., 2001; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008).

The presence of depressive symptoms is also associated with decreased sensitivity to gains, but increased sensitivity to losses (Berenbaum & Oltmanns, 1992; Carver, Johnson, & Joormann, 2008; Gotlib & Joormann, 2010; Henriques & Davidson, 2000; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008). For example, individuals with depressive symptoms exhibit attenuated responses to monetary gains (Henriques & Davidson, 2000), but hypersensitive behavioral and electrophysiological responses to losses (Eshel & Roiser, 2010; Gotlib & Joormann, 2010; Holmes & Pizzagalli, 2008; Murphy, Michael, Robbins, & Sahakian, 2003). In fact, in a recent fMRI study, Robinson et al (2012) localized this effect in depression to the ventral striatum in a reversal learning task. They found attenuated ventral striatal responses to reward stimuli, but not to punishment stimuli.

These findings are consistent with the suggestion that individuals with depressive symptoms possess bio-behavioral motivation systems (Fowles, 1994) that increase sensitivity to punishment and generate negative affect (Kasch, Rottenberg, Arnou, & Gotlib, 2002). Thus, decision-making may not be deficient in individuals with depressive symptoms, but rather may result from an emphasis on gain-maximization. This suggests that decision-making may actually be enhanced in individuals with depressive symptoms under conditions that emphasize prevention of loss, but this idea has not yet been tested.

Interestingly, the decision-making deficits that have been observed in individuals with depressive symptoms have all been obtained under gain-maximization conditions (Gradin et al., 2011; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008). For example, Pizzagalli et al (2008) used a signal detection task in which participants judged whether the mouth on a schematic face was 'short' or 'long' and were rewarded with a small amount of money (e.g., 5 cents) for correct responses, and no money for errors. Participants were instructed to maximize money earned. It is possible that the observed decision-making deficits in individuals with depressive symptoms might be due to reduced sensitivity to gains. In fact, because depressive symptoms are associated with enhanced sensitivity to losses, it is possible that individuals with depressive symptoms will show decision-making advantages under loss-minimization conditions.

The goal of this study is to examine decision-making in individuals who are high (depressive) or low (non-depressive) in depressive symptoms and to test the hypothesis that depressives' decision-making is deficient under gain-maximization conditions, but is enhanced under loss-minimization conditions. We use the Mars Farming task that we have used previously (Worthy, Gorlick, Pacheco, Schnyer, & Maddox, 2011) and has been used

extensively in the decision-making literature (Gureckis & Love, 2009a, , 2009b; Herrnstein & Prelec, 1991). The Mars Farming Task is referred to as a history-dependent decision-making task because the currently available options and their associated rewards depend upon the previous history of choices (Worthy, Gorlick, Pacheco, Schnyer, & Maddox, 2011; Worthy & Maddox, 2012). The optimal strategy (i.e., the strategy that maximizes cumulative reward) is to forgo the immediately rewarding option in favor of an option that will increase future rewards. Decision-making situations like this are prevalent in everyday life, and represent some of the most important decisions that we make. For example, long-run health and well-being require a nutritious diet and exercise, thus forgoing sweets and sedentary behavior. Analogously, obtaining a high paying job in the future requires forgoing a modest paying job today and instead attending college. To our knowledge this important and prevalent choice history-dependent form of decision-making has not been examined in individuals with depressive symptoms.

Because depressive individuals show deficient gain/reward processing and enhanced loss/punishment processing, we predict that depressive individuals will be better able to learn the optimal decision-making strategy in the losses environment, while non-depressives will be better equipped to learn the optimal decision-making strategy in the gains environment.

2. Method

2.1 Participants

Participants were 191 adults recruited from the University of Texas community, with 92 participating in the gain-maximization condition and 99 participating in the loss-minimization condition (Table 1). On average, the sample was 21.38 years old, female, and educated, with many currently enrolled at the University¹. Participants were recruited using flyers posted in the community and with ads posted on the Web. Interested participants were asked demographic questions and were screened for the presence of depressive symptoms. We then actively recruited depressive and non-depressive participants to serve in the study. Participants received \$10 for their participation with the average laboratory session taking about 50 minutes². Inclusion criteria included normal or corrected-to-normal vision and English language fluency.

2.2 Depression Classification

At the beginning of the experimental session, each participant was administered the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). Following convention (Welssman, Sholomskas, Pottenger, Prusoff, & Locke, 1977), participants who obtained a score of 15 or less were classified as non-depressive and participants who obtained a score 16 or greater were classified as depressive. CES-D scores of 16 or greater reflect mild or greater symptoms of depression (Radloff, 1977). In prior work with a sample that is demographically similar to the current study sample (Shean & Baldwin, 2008), non-depressed individuals had a mean CES-D score of 9 whereas participants diagnosed with Major Depressive Disorder (MDD) had a mean CES-D score of 27. We obtained similar CES-D means using a cut-score of 16 to define our non-depressive and depressive groups (see Table 1). This suggests that many of our depressive participants were likely experiencing significant symptoms of depression; however, MDD was not assessed. In addition, medication history, therapy history, and comorbid mental or physical health problems were not assessed. Nevertheless, comparing groups high and low in depression severity is consistent with prior research (e.g., Pizzagalli, Jahn, & O'Shea, 2005).

2.3 Materials and Procedures

A sample screen shot from a trial in the gain-maximization condition of the Mars Farming task is displayed in Figure 1A (left panel). Figure 1B (left panel) shows the reward structure for the task under gain-maximization conditions. Participants were asked to select one of two systems for extracting oxygen on each trial. They were given no prior information about the gains received for choosing one of two systems. Following each choice a small tank filled with the oxygen extracted on that trial. This was then transferred to a larger tank. A line on the larger tank corresponded to the amount of oxygen needed to sustain life on Mars, and participants were told to collect at least that much oxygen over the course of the experiment. The goal line was set at the equivalent of 18,000 points. This corresponded to selecting the optimal choice (increasing option) on approximately 80% of trials.

The gain associated with selecting each option is dependent on the number of times that one of the options, referred to as the *increasing* option, has been selected over the previous 10 trials. For example, if the increasing option had been selected on 4 of the previous 10 trials, then 50 units of oxygen would be extracted with the increasing option system, whereas 60 units of oxygen would be extracted with the decreasing option system. Choosing the increasing option causes the gain for both options to increase on future trials whereas choosing the other option, referred to as the *decreasing* option, causes the gain for both options to decrease on future trials. However, the decreasing option *always* gives a higher gain on any given trial, as suggested by the example above. Thus, on every trial the decreasing option will yield a higher gain, but the more that the increasing option is selected the larger the gain obtained for both options will be on future trials. Thus, there is a tension between the immediate and delayed benefit of choosing each option. Selecting the increasing option involves a cost in the immediate gain but a delayed benefit in overall gain, whereas selecting the decreasing option involves a benefit in the immediate gain but a delayed cost in overall gain. Critically, the increasing option should be selected on each trial to maximize cumulative payoff.

A sample screen shot from a trial in the loss-minimization condition of the Mars Farming task is displayed in Figure 1A (right panel). Figure 1B (right panel) shows the reward structure for the task under loss-minimization conditions. In the loss-minimization condition, participants were given a cover story where they were told that they would be testing two oxygen extraction systems that both extracted oxygen at the same rate but that emit carbon dioxide at different rates as a by-product. Participants were given no prior information about the amount of carbon dioxide emitted by each system. Participants were told only that their goal was to minimize the amount of carbon dioxide emitted in the task. A bar, representing a small carbon dioxide tank, displayed the amount of carbon dioxide emitted on each trial. This was then transferred into the larger tank and the next trial began. A line on the larger tank corresponded to the amount of carbon dioxide that could not be exceeded to sustain life on Mars, and participants were told to try to emit as little carbon dioxide as possible over the course of the experiment. The goal line was set at the equivalent of -7,000 points. This corresponded to selecting the optimal choice (increasing option) on approximately 80% of trials. In both conditions, participants performed a total of 240 trials. This task was programmed using Flash Professional 8. An exit screen provided information about whether they reached their goal or not.

Importantly, the gain-maximization and loss-minimization conditions are “yoked” in the sense that the losses in the loss-minimization condition are derived directly from the gains in the gain-maximization condition by subtracting a constant (100) from each reward value in Figure 1B. For example, whereas the maximum reward for selecting the decreasing option in the gain-maximization condition is 90, the minimum loss for selecting the decreasing option

in the loss-minimization condition is -10 . Thus, the optimal task strategy is equated across gain-maximization and loss-minimization conditions.

3. Results

To allow direct comparisons across the gain-maximization and loss-minimization versions of the task, we added 100 points to the outcome on each trial in the loss-minimization condition. We also examined the proportion of increasing option selections (Figure 2).

3.1 Total Points

The average point totals for the non-depressive and depressive participants in the gain-maximization and loss-minimization condition are displayed in Figure 2A. A 2 (depressive symptoms: non-depressive vs. depressive) $\times$ 2 (incentive: gain-maximization vs. loss-minimization) ANOVA on the total points revealed a significant main effect of incentive [$F(1, 187) = 11.52, p < .001, \eta^2 = .058$] and a significant interaction between depressive symptoms and incentive [$F(1, 187) = 62.04, p < .001, \eta^2 = .249$].

To determine the locus of the interaction between depressive symptoms and incentive, we conducted follow-up t-tests. First, we examined the effects of depressive symptoms separately in the two incentive conditions. In the gain-maximization condition, non-depressive participants performed significantly better than depressive participants [$t(90) = 5.48, p < .001, \eta^2 = .250$; non-depressed = 16220, depressed = 13268], but in the loss-minimization condition depressive participants performed significantly better than non-depressive participants [$t(97) = 5.77, p < .001, \eta^2 = .256$; non-depressive = 12572, depressive = 14719]. Next, we examined the effects of incentive condition separately for non-depressive and depressive participants. Non-depressive participants performed significantly better in the gain-maximization condition than in the loss-minimization condition [$t(96) = 8.52, p < .001, \eta^2 = .431$; gain-maximization = 16221, loss-minimization = 12572], but depressive participants performed significantly better in the loss-minimization condition than in the gain-maximization condition [$t(91) = 2.97, p < .01, \eta^2 = .089$; gain-maximization = 13268, loss-minimization = 14719].

3.2 Proportion of Increasing Option Selections

The average proportion of increasing option selections for the non-depressive and depressive participants in the gain-maximization and loss-minimization conditions are displayed in Figure 2B. A 2 (depressive symptom: non-depressive vs. depressive) $\times$ 2 (incentive: gain-maximization vs. loss-minimization) ANOVA on the proportion of increasing option selections revealed a significant main effect of incentive [$F(1, 187) = 11.81, p < .001, \eta^2 = .059$] and a significant interaction between depressive symptoms and incentive [$F(1, 187) = 60.11, p < .001, \eta^2 = .243$].

To determine the locus of the interaction between depressive symptoms and incentive, we conducted follow-up t-tests. First, we examined the effects of depressive symptoms separately in the two incentive conditions. In the gain-maximization condition, non-depressive participants selected the increasing option significantly more often than depressive participants [$t(90) = 5.42, p < .001, \eta^2 = .246$; non-depressive = .70, depressive = .38], but in the loss-minimization condition depressive participants selected the increasing option significantly more often than non-depressive participants [$t(97) = 5.63, p < .001, \eta^2 = .246$; non-depressive = .31, depressive = .53]. Next, we examined the effects of incentive condition separately for non-depressive and depressive participants. Non-depressive participants selected the increasing option significantly more often in the gain-maximization condition than in the loss-minimization condition [$t(96) = 8.46, p < .001, \eta^2 = .427$; gain-maximization = .70, loss-minimization = .31], but depressive participants selected the

increasing option significantly less often in the gain-maximization condition than in the loss-minimization condition [$t(91) = 2.87, p < .01, \eta^2 = .083$; gain-maximization = .38, loss-minimization = .53].

3.3 Depressive Symptom Severity and Performance

We found that non-depressive participants outperformed depressive participants in the gain-maximization condition, but that depressive participants outperformed non-depressive participants in the loss-minimization condition. To determine whether depressive symptom severity leads to enhanced effects, we correlated the CES-D scores with total points and the proportion of increasing option selections separately in the gain-maximization and loss-minimization conditions. We found support for the prediction that increased depression severity is associated with worse performance in the gain-maximization condition (total points: $r(90) = -.28, p < .01$; proportion increasing option selections: $r(90) = -.28, p < .01$), but is associated with better performance in the loss-minimization condition (total points: $r(97) = .36, p < .001$; proportion increasing option selections: $r(97) = .35, p < .001$).

3.4 An Alternative Depression Classification Scheme

The analyses outlined above all used a CES-D cutoff approach for which individuals with a CES-D score of 16 or greater were classified as depressive, whereas those with a score of 15 or less were classified as non-depressive. We also conducted an “extreme-scores” analysis in which we classified individuals with a CES-D score of 20 or greater as depressive, and those with a score of 10 or less as non-depressive. All of the findings in Figure 2 replicated suggesting that the findings are general and are robust to different classification schemes.

4. General Discussion

Depression has been associated with deficits in decision-making (Butters et al., 2004; Elderkin-Thompson, Mintz, Haroon, Lavretsky, & Kumar, 2006; Gradin et al., 2011; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008; Rogers et al., 2004). However, these deficits have been observed only under gain-maximization conditions (Gradin et al., 2011; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008). Since depression is associated with decreased sensitivity to gains, but enhanced sensitivity to losses, it is possible that depressed individuals might show superior decision-making when the task is framed with respect to loss-minimization.

We found support for this hypothesis in a large sample of individuals who score high (depressive) and low (non-depressive) in the presence of depressive symptoms using a history-dependent decision-making task for which the optimal strategy is to forgo the immediately rewarding option in favor of the alternative that maximizes cumulative delayed reward. We found that depressive individuals were superior to non-depressive individuals under loss-minimization conditions, but were inferior to non-depressive individuals under gain-maximization conditions. In addition, we found superior loss-minimization than gain-maximization performance for depressive individuals, but superior gain-maximization than loss-minimization performance for non-depressive individuals.

Prior work suggests that decision making is optimized when the task framework matches a person's regulatory style (Maddox & Markman, 2010), including work using tasks very similar to those used in the current study (Otto, Markman, Gureckis, & Love, 2010). Thus poor decision making performance may be a byproduct of the fact that most decision-making tasks emphasize maximizing gains, which may be a poor fit for a person whose regulatory style generally emphasizes loss minimization, as in depression (c.f., Higgins, 1997). Indeed, our data strongly suggest that decision-making is significantly improved for depressive individuals when they are trying to avoid losses rather than maximize gains.

We believe these findings may have very important implications for understanding depressive decision-making. First, it suggests that global decision-making deficits are not necessarily a characteristic of depression; rather, depressive people may excel at decision making under conditions that emphasize sensitivity to loss and negative outcomes rather than gain and rewards (for related work see, Robinson, Cools, Carlisi, Sahakian, & Drevets, 2012). Second, this research offers a simple mechanism by which one could enhance decision-making when depressive symptoms are present and thus could improve the depressives' quality of life—decision making could be reframed as loss-minimization problems instead of gain-maximization problems. This can be achieved very simply, for example, by instructing an individual to minimize errors as opposed to maximize accuracy. Future research should continue to examine whether this subtle reframing of decision making problems leads to improved decision making among depressed people, particularly for important real world outcomes (e.g., major life decisions; Galotti, 2007).

5. Conclusions

We examined decision making in depressive and non-depressive individuals under gain-maximization and loss-minimization conditions using a task for which the currently available rewards depend upon participants' previous history of choices. We found a cross over interaction whereby depressive individuals were superior to non-depressive individuals under loss-minimization conditions, but were inferior to non-depressive individuals under gain-maximization conditions. These results suggest that decision making deficits observed in depressed individuals may be attenuated when decisions involve minimizing loss rather than maximizing gains.

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Figure 1.

(A) Screen shot from one trial of the Mars Farming Task under the gain-maximization (left panel) and loss-minimization (right panel) conditions. (B) Rewards given as a function of the number of increasing option selections over the previous ten trials. Points were linearly transformed into either oxygen gained (left panel) or carbon dioxide emitted (right panel). In the gain-maximization condition the reward for selecting the increasing option = $30 + 5h$ and the reward for selecting the decreasing option = $40 + 5h$ where h = the number of increasing option selections in the last 10 trials. In the loss-minimization condition the reward for selecting the increasing option = $-70 + 5h$ and the reward for selecting the decreasing option = $-60 + 5h$ where h = the number of increasing option selections in the last 10 trials. Thus, rewards for the loss-minimization task were derived by subtracting 100 points from each reward in the gain-maximization condition. The optimal strategy was to repeatedly select the increasing option.

Figure 2. (A) Total points and (B) Proportion of Increasing Option Selections obtained for the Gain-Maximization and Loss-Minimization participants in the Experiment. Standard error bars are included.

Table 1

Experiment Demographic Characteristics

	Non-Depressive		Depressive	
	Gain Maximization	Loss Minimization	Gain Maximization	Loss Minimization
N	45	53	47	46
Age: mean (sd)	21.25 (3.35)	22.49 (4.86)	20.47 (3.34)	21.09 (3.72)
Gender (m/f)	22/23	21/32	20/27	18/28
CES-D: mean (sd)	7.97 (4.10)	9.62 (3.65)	24.77 (8.96)	25.85 (10.19)