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Influence of depression symptoms on history-independent reward and punishment processing

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ABSTRACT

Prior research indicates that depressed individuals are less responsive to rewards and more sensitive to punishments than non-depressed individuals. This study examines decision-making under reward maximizing or punishment minimizing conditions among adults with low (n=47) or high (n=48) depression symptoms. We utilized a history-independent decision-making task where learning is experience-based and the participants' goal is to enhance immediate payoff. Results indicated a significant interaction between incentive condition (reward maximizing, punishment minimizing) and depression group. Within the low depression group, better performance was observed for reward maximization than punishment minimization. In contrast, within the high depression group, better performance was observed for punishment minimization than reward maximization. Further, the high depression group outperformed the low depression symptom group in the punishment minimization condition, but no depression group differences were observed in the reward maximization condition. Computational modeling indicated that the high depression group was more likely to choose options with the highest expected reward, particularly in the punishment condition. Thus, decision-making is improved for people with elevated depression symptoms when minimizing punishment relative to maximizing rewards.

1. Introduction

Depression is a common and impairing condition that predicts a number of negative outcomes, such as future suicide attempts, interpersonal problems, unemployment, and substance abuse (Kessler and Walters, 1998; Kessler et al., 2003). The World Health Organization estimates that 121 million people are currently suffering from depression, and it is the leading cause of disability worldwide among people 5 years of age and older. Given its high prevalence, it is perhaps not surprising that the annual economic cost of major depressive disorder (MDD) in the U.S. alone is over $70 billion in medical expenditures, lost productivity, and other costs (Greenberg et al., 1993; Philip et al., 2003).

Depression is consistently associated with biased processing of negative information (Gotlib and Joormann, 2010). Depressed individuals focus on negative self-referent thoughts and exhibit enhanced effortful recall of negative-valence material (Mathews and MacLeod, 2005). Similarly, depressed individuals are hypersensitive to negative feedback and punishment (Eshel and Roiser, 2010). For instance, depressed people are more likely than controls to revert back to a previously learned rule following non-contingent negative feedback (Murphy et al., 2003). This effect appears to be specific to unipolar depression, as bipolar participants experiencing a depressive episode do not display sensitivity to non-contingent punishment whereas people with unipolar depression do show this bias (Taylor Tavares et al., 2008). Depressed people also display greater electrophysiological response to errors than controls (Holmes and Pizzagalli, 2008). These findings are consistent with the suggestion that depressed individuals possess bio-behavioral motivation systems (Fowles, 1994) that increase sensitivity to punishment and generate negative affect (Kasch et al., 2002). Given this sensitivity to negative outcomes, decision-making may be enhanced in depression when the goal is to minimize punishment.

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Depression is also associated with decreased sensitivity to rewarding stimuli (Berenbaum and Oltmanns, 1992; Henriques et al., 1994; Gotlib and Joormann, 2010). For example, depressed individuals exhibit attenuated responses to pleasant drinks (Berenbaum and Oltmanns, 1992) and monetary rewards (Henriques et al., 1994). Depressed individuals also are more inconsistent in their decision-making when trying to delay receipt of rewards (Takahashi et al., 2008) and tend to be more conservative in their decision-making, even when the likelihood of receiving a reward is high (Murphy et al., 2001). Further, on a probabilistic reward learning task, depressed individuals displayed significantly reduced reward responsiveness compared to healthy controls. Trial-by-trial analyses indicated that depressed individuals were less likely than controls to rely on past reinforcement history to guide current decision-making, particularly in the absence of an immediate reward (Pizzagalli et al., 2008; Gradin et al., 2011). Poor responsiveness to rewards predicts a more protracted course of depression (Kasch et al., 2002).

Taken together these data suggest that depression is associated with intact or increased sensitivity to punishment and reduced sensitivity to reward. Although these findings are important, and motivated the current work, what is lacking is an integrated empirical examination of the effects of incentives (reward vs. punishment) and depression symptoms on decision-making. In other words, few studies have examined reward and punishment processing within the same subjects using decision-making tasks that are directly comparable. Most prior studies have used between subjects designs and/or only studied punishment or reward processing in isolation. By studying reward and punishment processing within the same subjects using tasks that are directly comparable, we will be able to assess the relative performance of depressed and non-depressed individuals across incentive conditions. This should yield a more comprehensive test of incentive processing in depression than many prior studies.

Another important feature of this study is the focus on history independent decision-making. History independent decision-making refers to circumstances where rewards for current decisions are independent of the choices that were made in the past (Worthy et al., 2011; Worthy and Maddox, 2012). That is, the level of reward received for any given trial does not depend on the level of reward received for prior decisions. For example, the probability of winning money by selecting red on the roulette wheel is independent of whether red was picked previously. When current rewards do not depend upon previous choices, decision-making is history independent. This is in contrast to history-dependent tasks, where the level of reward for a given trial is in part dictated by past decisions.

However, it is important to note that, unlike playing roulette, participants still need to learn from past decisions to perform well on history-independent decision-making tasks. These are decision-making problems for which the gains and losses are unknown and one must learn about them from experience. Over time, participants can learn which choices provide large rewards or most effectively minimize losses. So, even though the rewards are distributed in a history independent fashion, learning about the nature of the decision-making environment can lead to enhanced performance. Such decision-making relies on information processing strategies that involve learning the values associated with each choice directly, and do not require developing a complex mental model of the environment. Learning simply involves choosing the option that maximizes immediate payoff. This is in contrast to other paradigms where decisions are made under risk—the probabilities of gain or loss for each option are known but they differ in risk (Kahneman and Tversky, 1979; Murphy et al., 2001). Decision-making on the history independent task is dependent on experience—that is, people learn which options have the highest reward (or minimize losses) over time.

Depressed individuals may be particularly good at history independent tasks. Depression is typically associated with performance deficits in tasks that tap effortful, reflective information processing. For instance, depressed individuals display difficulties with effortful problem-solving (Elderkin-Thompson et al., 2006), planning (Rogers et al., 2004), and cognitive flexibility (Butters et al., 2004). Depressed individuals also have memory deficits (Burt et al., 1995), particularly in free recall tasks and other tasks that require controlled aspects of recognition (Hertel, 1998; Dalgleish et al., 2007). With sufficient external support, however, cognitive performance can be improved (Hertel and Rude, 1991). In contrast, performance remains intact when optimal performance relies on automatic, reflexive information processing (Hartlage et al., 1993). Depressed individuals have sufficient cognitive resources for non-cognitively demanding tasks, but performance suffers when required to engage or control cognitive resources (Hertel, 1994).

Taken together, these data suggest that depression is associated with intact or nearly intact performance in tasks that require automatic, reflexive processing, such as history independent decision-making tasks. Further, increased sensitivity to punishment should facilitate learning the task options that produce the least amount of punishment (i.e., smallest point loss). Decision-making performance may therefore be enhanced in depression when the goal is to minimize punishments in a history independent decision-making task. Testing this hypothesis is the main goal of this study.

A secondary goal is to examine how depression affects reward processing on a history-independent decision-making task. On the one hand, the relatively effortless processing required to perform a history independent task should not be disrupted in depression (Hartlage et al., 1993). However, as noted above, depression is associated with reduced responding to rewards. Thus, an exploratory aim is to determine whether depression disrupts reward processing on a history-independent decision-making task.

To achieve these aims, participants completed two history-independent decision-making tasks that are identical except in one version participants are instructed to minimize punishments and in the other version they are instructed to maximize rewards. Thus, we can directly examine how depression influences decision-making performance within each incentive condition. This allows for a rigorous and comprehensive test of whether depression interacts with incentive structure (reward vs. punishment) to predict decision-making performance. Finally, computational modeling was used to assess the cognitive processes that give rise to any observed group differences in decision-making performance.

2. Methods

2.1. Participants

Participants were 95 adults recruited from the Austin, Texas community (see Table 1 for demographic information). On average, the sample was 19.69 years old, female, and educated.[1] Participants were recruited using flyers posted in the community and with ads posted on the Web. Participants received $10 for their participation in the 50-min study. Inclusion criteria included normal or corrected-to-normal vision and fluency in the English language.

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).

[1] All analyses reported below were also examined with age and gender as a factor. In no case did neither measure yield a significant main effect, nor did they interact with any other factor.