Neural Responsiveness to Reward as a Moderator of the Effect of Rejection Sensitivity on Depressive Symptoms

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INTRODUCTION

The Research Domain Criteria (RDoC) initiative incorporates multiple levels of analysis, including neurobiology, to inform our understanding and classification of psychopathology (National Institute of Mental Health, 2020). The RDoC framework emphasizes the study of several domains, including positive valence systems, and characterizes psychopathology as deviations from a typical range of functioning (Cuthbert, 2014). Research on the positive valence system domain has provided particularly useful insights into the development of depression (Kujawa & Burkhouse, 2017). Specifically, alterations in one of the constructs within the positive valence system domain, reward responsiveness, have been associated with psychopathology (Keren et al., 2018; Kujawa & Burkhouse, 2017).

One reliable neurophysiological measure that has been used to examine individual differences in initial reward responsiveness is the reward positivity (RewP), also known as the feedback negativity in the electroencephalogram (EEG) literature. This event-related potential (ERP) is a relative positivity in the waveform that peaks about 300 ms following positive feedback and rewards relative to loss or neutral feedback over frontocentral sites (Bress et al., 2015; Kujawa et al., 2018; Proudfit, 2015). Research has also found an association between RewP and self-report measures of reward responsiveness and positive emotionality (Kujawa et al., under review). In the functional magnetic resonance imaging literature, RewP has been associated with activation in brain regions involved in reward processing, including the ventral striatum and medial prefrontal cortex (Becker et al., 2014; Carlson et al., 2011).

Much of the research on neurophysiological response to reward and depression has been conducted using monetary reward tasks measuring the ERP after an individual receives feedback indicating a monetary win or loss. Findings from this research suggest that a reduced RewP to monetary reward is associated with depression and may be a vulnerability that prospectively predicts increases in symptoms (Bress, Foti, et al., 2013; Kujawa & Burkhouse, 2017; Kujawa, Burkhouse, et al., 2019; Kujawa, Hajcak, et al., 2019; Nelson et al., 2016). Those with reduced neurophysiological response to reward may have greater difficulty finding motivation to engage in and experience pleasure from positive and social activities (Setterfield et al., 2016), which may lead to the later onset of depression. This may be particularly relevant when individuals are under stress. Consistent with this, research has shown that a reduced RewP prospectively predicts depression in children and adolescents in combination with stress (Goldstein et al., 2019). At the same time, associations between reward responsiveness and depressive symptoms tend to be relatively weak in magnitude (Kujawa & Burkhouse, 2017), which may be due in part to a lack of precision in monetary reward tasks in terms of their ability to assess the core vulnerabilities underlying depression risk. In considering pathways to depression, *interpersonal* stress and processes are particularly strong risk factors for depression (Hammen, 2005; Henry et al., 2019; Kessler et al., 2010). Research suggests that a low social reward responsiveness appears to be a relatively specific vulnerability for interpersonal rather than non-interpersonal stress (Pegg et al., 2019). Because of potential differences in social compared to monetary reward responsiveness and the relevancy of social processes in the onset and development of depression, additional work is needed examining the implications of social reward responsiveness on pathways to depression.

Another known precursor to depression that may interact with stress is high sensitivity to rejection (Ayduk et al., 2001; Liu et al., 2014), which has also been shown to prospectively predict change in depressive symptoms (De Rubeis et al., 2017). Individuals high in rejection sensitivity experience more negative emotions when faced with potential rejection (Downey & Feldman, 1996; Leng et al., 2018). Given that reward responsiveness may be a vulnerability to depression, and rejection sensitivity may increase one's risk for developing symptoms, it is possible that reward responsiveness may moderate the relation between rejection sensitivity and depression. That is, those high in rejection sensitivity who also experience *reduced* responsiveness to positive reinforcement may be at greatest risk for depression. These patterns may be particularly apparent when examining the social rather than monetary reward domain, given its more direct relevance to the experience of emotion in interpersonal contexts. Yet, to our knowledge, no prior studies have directly compared associations of monetary and social reward responsiveness with depression and as moderators of the effects of other established depression precursors, like rejection sensitivity.

Although previous work examining RewP and depression has been conducted primarily using monetary reward tasks (Kujawa & Burkhouse, 2017; Proudfit, 2015), there is growing evidence that similar neural responses can be elicited to social reward feedback in peer interaction tasks (Crowley et al., 2010; Ethridge et al., 2017; Kujawa et al., 2014; Sun & Yu, 2014). There is conflicting evidence in the literature regarding whether neural systems underlying reward responsiveness are the same across domains of reward (e.g., Lin et al., 2012), or whether there are differences in processing based on the type of reward being evaluated (e.g., Ethridge et al., 2017). One recent study directly compared social and monetary reward within subjects in a non-clinical sample of emerging adults and used principal component analysis

(PCA) to empirically derive the ERP components in response to reward to better isolate potentially unique characteristics of RewP by reward type (Ethridge et al., 2017). Traditionally, ERP components are scored using averaged activity in microvolts across a specified time window, which is typically based on visual inspection and the literature. By using PCA, the authors were able to examine whether a component consistent with RewP on each task was present in the data that did not include any overlapping components in the ERP wave. In this study, the magnitude of RewP to monetary reward was larger compared to RewP to social reward (Ethridge et al., 2017), suggesting that response to reward may differ by reward type. Additionally, RewP to social reward were not significantly correlated with RewP to monetary reward, suggesting the two measures may index somewhat distinct reward-related processes (Ethridge et al., 2017). The study also showed within the same subjects that social RewP appears to peak slightly later (about a 25 ms delay) compared to monetary RewP, which may perhaps reflect added complexity of processing social feedback compared to a monetary win or loss (Ethridge et al., 2017). There are other conceptual limitations to relying on monetary reward tasks to study reward responsiveness. For example, there are individual differences in valuation of the same amount of money. Further, monetary reward tasks vary in terms of the amount of money offered as a reward, which has been shown to impact task engagement (Gneezy & Rustichini, 2000). Social reward, on the other hand, may be a stronger and more reliable predictor of social behaviors and psychopathology (Davey et al., 2008; Forbes & Dahl, 2012; Silk et al., 2012). Taken together, the extant literature suggests that neural response to reward may differ by reward type and that additional research is needed to examine the associations between different types of reward and depression.

Pathways to depression are complex, and there are likely multiple factors at play that interact to increase one's likelihood of developing depression. To extend research on neurophysiological measures of reward responsiveness in depression, it is important to consider more complex pathways and interactions between multiple factors. It is possible individuals who exhibit both high rejection sensitivity and low reward responsiveness, particularly to social rewards, may be at greatest risk for depressive symptoms. In the present study, we propose to test interactions between two potential vulnerabilities for depression, as well as examine the extent to which effects of reward responsiveness on depression emerge for both social and monetary reward. Specifically, we tested the extent to which reward responsiveness moderates the association between self-reported rejection sensitivity and depressive symptoms, such that the combination of low reward responsiveness, especially in the social domain, and high rejection sensitivity may be associated with greater depressive symptoms. During one study visit, an unselected sample of emerging adults completed self-report measures of rejection sensitivity and recent depressive symptoms. They also completed two EEG tasks designed to assess reward responsiveness, one assessing social reward (i.e., peer acceptance feedback) and one assessing monetary reward. PCA was used to identify and isolate components consistent with RewP in each EEG task. Based on the current literature suggesting that social reward responsiveness may moderate the effects of other interpersonal processes on depressive symptoms (Pegg et al., 2019), we predicted that neural response to social reward would moderate the relation between rejection sensitivity and depressive symptoms while response to monetary reward would not.

CHAPTER 2

METHOD

Participants

Undergraduate students between the ages of 18-22 years were recruited via flyers and the psychology research participant pool. Participants were compensated with research credit or $30 for participating in a larger EEG assessment. Following written informed consent, participants completed questionnaires and 4 counterbalanced EEG tasks (the results of other tasks will be presented in future manuscripts; Pegg & Kujawa, 2020). A total of 129 participants enrolled in the study, of which 3 were excluded for having poor EEG data quality for reference electrodes and 5 were excluded for poor EEG data quality on at least 11 channels that required interpolation across both tasks. One participant did not complete the self-report rejection sensitivity measure and was excluded. Thus, 120 participants were included in analyses. The mean age of the sample was 19.32 (*SD* = 1.15), and 66.7% (*n* = 80) of the sample identified as female and 10.8% (*n* = 13) identified as Hispanic or Latinx. In terms of race, participants identified as White (54.2%, *n* = 65), Asian (25.0%, *n* = 30), Black (10.8%, *n* = 13), or other or mixed race (10.0%, *n* = 12). Additionally, on the social reward task, 1 participant was excluded for poor EEG data quality on at least 11 channels that required interpolation, 1 participant was excluded because they requested that their data would not be used following debriefing for this task, and 1 participant was excluded on this task due to technical difficulties during data collection, resulting in a total of 117 participants with viable data on this task. On the monetary reward task, 3 participants did not complete the task, 3 were excluded for failure to follow task instructions, and 1 was excluded for poor EEG data quality on at least 11 channels that required interpolation, resulting in a total of 113 participants with viable data on this task. All study procedures were approved by the Vanderbilt University Institutional Review Board, and informed consent was obtained from all participants prior to the start of study procedures.

Measures

Island Getaway Social Reward Task

Participants completed the Island Getaway social reward task while EEG data were collected (Kujawa et al., 2014; Figure 1A). In this "Survivor"-style game, participants virtually "traveled" to the Hawaiian Islands with a group of 13 computerized coplayers that they were made to believe were other college students playing the game in real time at universities across the United States. Participants had their photograph taken as part of a profile that they built for themselves by answering several questions, including their name, age, university, and general interests. They then read the profiles of the coplayers. Participants were instructed that they would vote on each player over several rounds and then would receive feedback on how each player voted for them. The player with the most votes to leave the game would be kicked out. The goal of the game was for the participant to make it to the final island without being voted off by their co-players. During each round, participants were presented with the profile of each coplayer remaining in the game and decided to vote to accept (i.e., "Keep") or reject (i.e., "Kick out") each player while that player simultaneously voted to accept or reject the participant. Participants had 5000 ms to vote. This was followed by a fixation cross for 2000 ms. The participant was then given feedback about how that coplayer voted for them for 2000 ms. If the coplayer voted to keep them, they received a green thumbs up. If the coplayer voted to kick them out, they received a red thumbs down. There was also a third form of feedback (i.e., a yellow rectangle) that indicated that no vote was received for the participant possibly due to a network error. Feedback presentation was followed by a fixation cross for 1500 ms before the start of the next trial. Participants were told at the end of each round that another player was kicked out of the game for having the most "kick" votes. The task was programmed such that the participant always made it to the final island after a total of 6 rounds. Across the task, participants received equal (i.e., 21 trials each) acceptance, rejection, and no-vote feedback for a total of 63 trials.

Monetary Incentive Delay (MID) Task

Participants also completed the ERP version of the MID task while EEG data were collected (K. D. Novak & Foti, 2015; Figure 1B). On each trial, participants first saw a cue for 500 ms that indicated whether the trial would be a monetary incentive trial (i.e., a blue dollar sign in a circle) or a non-incentive trial (i.e., a white outline of a circle). A fixation cross was then presented for 2000-2500 ms. A target (i.e., a white square) was then presented, which participants were instructed to respond to by clicking the left mouse button. This was followed by another fixation cross for a total of 1500 ms from target onset to feedback onset. On incentive trials, if the participant responded within the target window, they received a monetary reward of $0.40 and saw a green up arrow. If they did not respond within the target window, they received a monetary loss of $0.20 and saw a red down arrow. On non-incentive trials, participants did not win or lose money and were presented with a yellow line regardless of reaction time. The target was initially presented for 200 ms and presentation time decreased by 10 ms if the participant was successful on the previous trial and increased by 10 ms if the participant was unsuccessful.

Task difficulty was adjusted such that participants won about 50% of the trials. Participants completed 70 total trials, including 50 incentive and 20 non-incentive trials. The difference in win versus loss amounts allowed participants to earn money, and participants were paid their total earnings. The inclusion of non-incentive trials in this task allows for the differentiation of ERP components between and reaction time to non-incentive versus potential win feedback during the anticipation of feedback stage of reward processing.

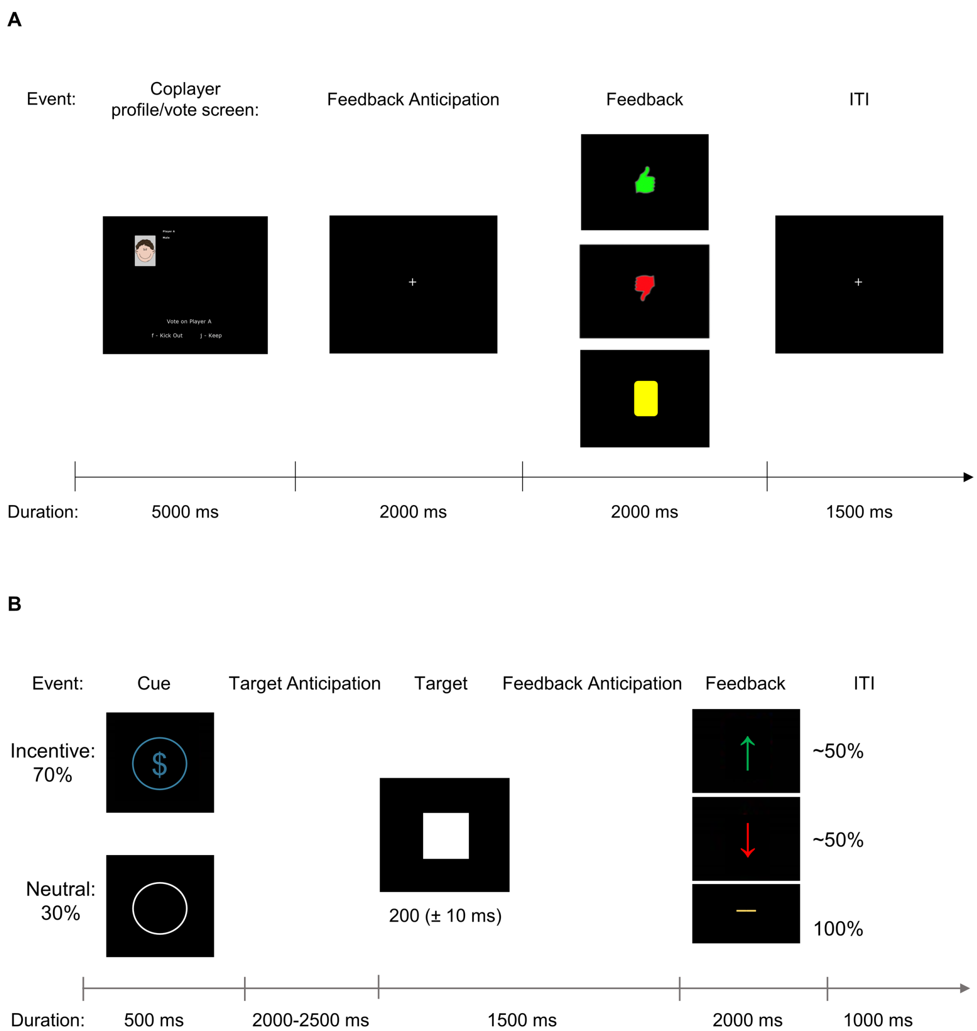

Figure 1. Example of a trial of (A) the Island Getaway social reward task (Kujawa et al., 2014) and (B) Monetary Incentive Delay task (K. D. Novak & Foti, 2015).

Rejection Sensitivity

As a measure of rejection sensitivity, participants completed the Rejection Sensitivity Questionnaire – Adult version (ARSQ; Berenson et al., 2009). The ARSQ consists of 9 hypothetical interpersonal situations in which rejection is possible (e.g., "You call a friend when there is something on your mind that you feel you really need to talk about"). Participants respond to two questions that assess how concerned or anxious the participant would feel if they were rejected in this situation from 1 (*very unconcerned*) to 6 (*very concerned*) and how much they would expect to be accepted in this situation from 1 (*very unlikely*) to 6 (*very likely*). For each hypothetical situation, a rejection sensitivity score is calculated by multiplying the level of rejection concern by the reverse score of acceptance expectancy. Then an average is calculated across all nine situations for an overall rejection sensitivity score, such that higher scores indicate higher levels of rejection sensitivity. ARSQ scores have been correlated with other indicators of interpersonal sensitivity and internalizing symptoms (Berenson et al., 2009). Internal consistency across the nine situations was good in the present sample (Cronbach's $\alpha = .80$).

Depressive Symptoms

Participants completed the Inventory of Depression and Anxiety Symptoms (IDAS), a 64-item, validated measure of recent (i.e., past two weeks) depressive and anxiety symptoms (Watson et al., 2007). There are two broad scales of depressive symptoms, the general depression scale and the dysphoria scale. The dysphoria scale focuses on the emotional and cognitive symptoms of depression, whereas the general depression scale consists of items assessing a larger range of depressive symptoms, such as fatigue and suicidality, and more closely corresponds to traditional measures of depression, such as the Beck Depression Inventory (BDI-II; Beck et al., 1996). To encompass a broader range of depressive symptoms, the general depression scale was used as a measure of depressive symptoms in the present study. Items are rated from 1 (*Not at all*) to 5 (*Extremely*). The IDAS has been found to have good internal consistency (Cronbach's $\alpha = .88$ - $.92$; Watson et al., 2007). The general depression scale has shown strong convergent validity with BDI-II (*r* = .83; Beck et al., 1996; Watson et al., 2007) and good test-retest reliability (*r* = .84; Watson et al., 2007). Scores on the IDAS general depression scale had excellent internal consistency in the present sample (Cronbach's α = .90). Of the 120 participants with IDAS general depression scores, 15.0% (*n* = 18) met the IDAS clinical cutoff for major depressive disorder (Stasik-O'Brien et al., 2019), suggesting that there was meaningful variance in depressive symptoms in this non-clinical sample.

EEG Data Collection and Processing

Continuous EEG data were collected using a 64-electrode BrainProducts actiCHamp system (Munich, Germany). To measure electrooculogram, facial electrodes were attached 1 cm above and below the right eye and 1 cm on each outer corner of the eyes, which were referenced to an electrode placed on the back of the neck per the BrainProducts bipolar-to-auxiliary adapter design. Impedances were lowered below 30 kΩ and the EEG signal had a sampling rate of 1000 Hz. Online data acquisition was referenced to Cz. Data were processed using BrainVision Analyzer (BrainProducts, Munich, Germany). A band-pass filter with cutoffs of 0.1 and 30 Hz was used. Data were re-referenced offline to linked mastoids TP9 and TP10. For both tasks, the continuous EEG data were segmented -200 ms before to 1000 ms after feedback. Ocular correction was conducted using Gratton's algorithm (Gratton et al., 1983). Semiautomatic artifact rejection was conducted with the following criteria: a voltage step greater than 50 µV/ms between sample points, maximum voltage difference of 175 µV within trials, a minimal allowed amplitude of -200 µV and maximal allowed amplitude of 200 µV, and minimum voltage difference of 0.5 µV within 100 ms intervals. Data were then visually inspected to remove any remaining artifacts. Data were then segmented by type of feedback (win/acceptance or loss/rejection) and baseline corrected -200 to 0 before feedback onset. For Island Getaway, participants had on average 20.79 (*SD* = 0.81) trials for the accept condition and 20.77 (*SD* = 0.65) trials for the rejection condition at Cz following artifact rejection. For MID, participants had on average 25.72 (*SD* = 1.59) trials for the win condition and 24.06 (*SD* = 1.58) trials for the loss condition at Cz following artifact rejection.

Data Analysis

Differentiating ERPs Modulated by Reward Responsiveness in Response to Social and Monetary Feedback

PCA was used to empirically derive the ERP components consistent with RewP because of the complexity and overlap in other components in the ERP wave (Ethridge et al., 2017). Two temporospatial PCAs were performed on each participant's averaged ERP data, one for responses to social reward feedback and one for responses to monetary reward feedback, using ERP PCA Toolkit, version 2.83 (Dien, 2010b). Because there is not a comparable unexpected neutral/no-vote feedback condition with the MID task and accept/win versus reject/loss conditions are commonly compared in the literature (e.g., Bress & Hajcak, 2013; Kujawa et al., 2014), the analyses focused on accept/win and reject/loss conditions. Based on the recommendations of previous studies (Dien, 2010a; Dien et al., 2005, 2007), a temporal PCA was performed prior to a spatial PCA. Time points from each participant's averaged data were variables. Participants, trial types, and recording sites were observations. Promax rotation was used for the temporal ERP data rotation to translate factors into simple structure in the temporal domain (Dien, 2010a). Following this rotation, a parallel test (Horn, 1965) was conducted on a

Scree plot (Cattell, 1966), in which the screes were derived from the dataset to compare against a random dataset. The largest number of factors that accounted for greater proporation of variance compared to the number of factors generated by the random dataset were obtained from each PCA. Based on this criterion, 29 temporal factors (TFs) were identified for the social reward task and 24 TFs were identified for the monetary reward task.

A spatial PCA was then conducted on each TF. Recording sites were variables. Participants, trial types, and TFs were observations. Infomax rotation was then used to transform data to independence (Dien, 2010a). Again, a parallel test was conducted with a Scree plot. Based on the results, 4 spatial factors (SFs) were obtained for both tasks in their separate PCAs. In each PCA, a component consistent with RewP emerged that peaked at 321 ms at FC2 as a relative positivity for social reward compared to rejection and 277 ms at FC2 as a relative positivity for monetary reward compared to loss. The temporospatial factors were converted to microvolt scaling and exported from ERP PCA Toolkit for further analysis. Component ERP waves and corresponding scalp distributions for each component before PCA are presented in Figure 2, and the PCA components are presented in Figure 3.

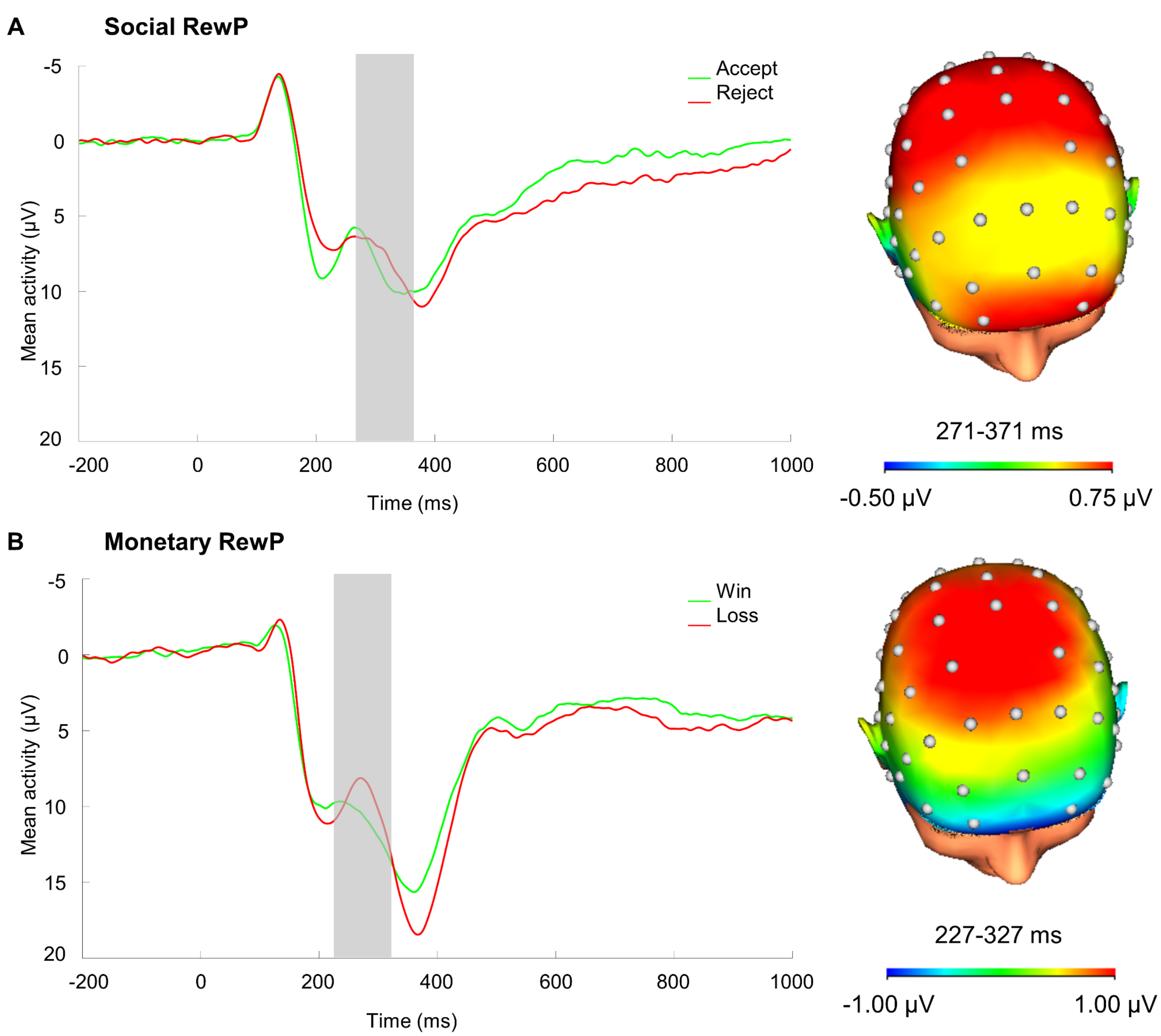

Figure 2. ERP waveform and scalp distributions for (A) RewP to social reward prior to PCA at FC2 and (B) RewP to monetary reward prior to PCA at FC2. Scalp distributions reflect the response to acceptance minus rejection and win minus loss difference scores. (64-channel montage with linked mastoid reference.)

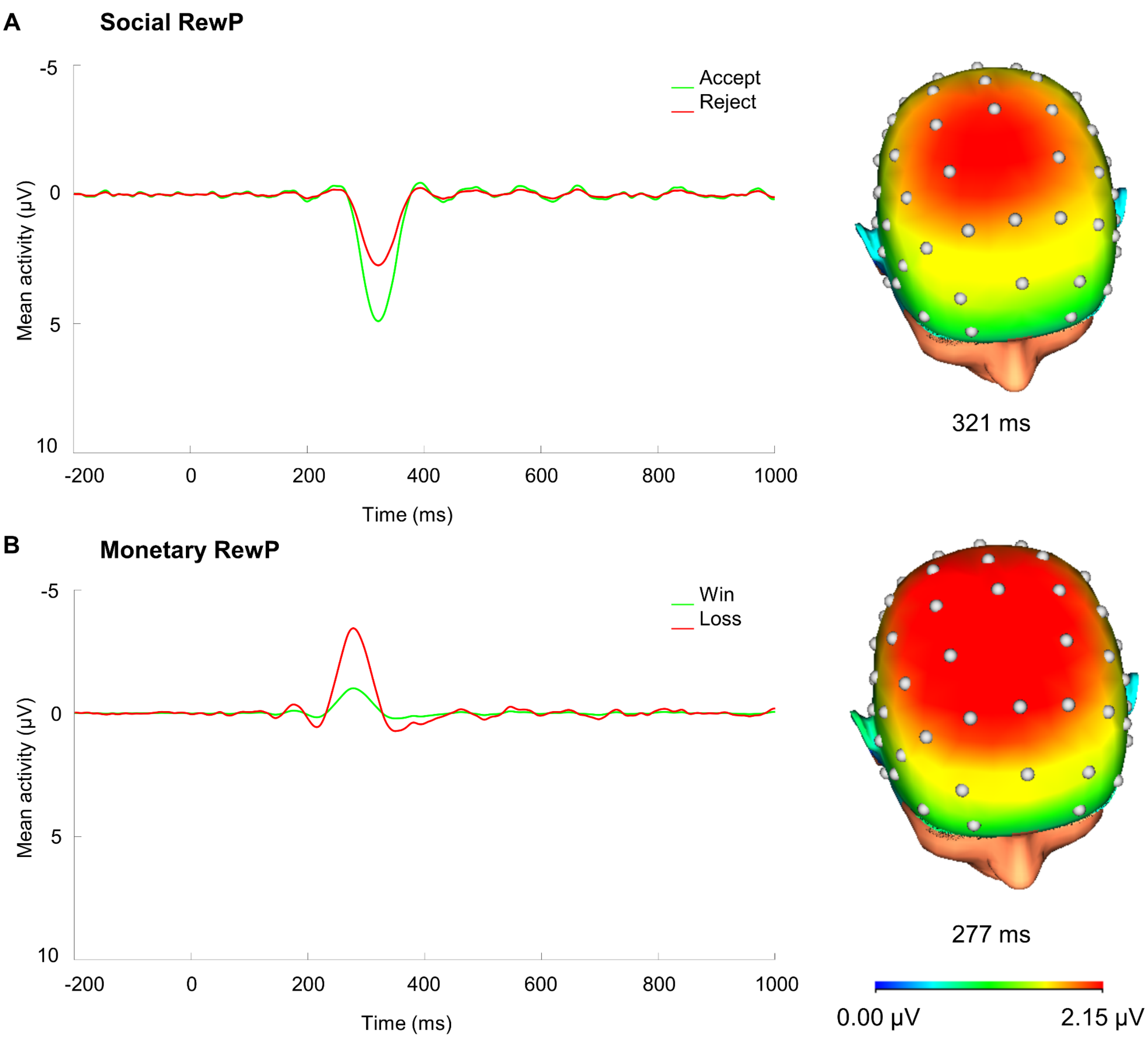

Figure 3. ERP waveform and scalp distributions for (A) RewP to social reward PCA peak at FC2 and (B) RewP to monetary reward PCA peak at FC2. Scalp distributions reflect the response to acceptance minus rejection and win minus loss difference scores. (64-channel montage with linked mastoid reference.)

Associations Between RewP, Rejection Sensitivity, and Depressive Symptoms

The RewP PCA temporospatial factor score was used as a measure of neural response to reward. Residual scores were calculated to isolate response to accept/win adjusting for response to reject/loss feedback by computing the unstandardized residuals of a linear regression model where RewP to acceptance or win feedback was the dependent variable and RewP to rejection or loss was the independent variable. To examine associations between neural response to reward, depressive symptoms, and rejection sensitivity, bivariate correlations were first conducted. Next, to test reward responsiveness as a moderator of the relation between rejection sensitivity and depressive symptoms, moderation analyses were conducted separately for social and monetary reward using PROCESS v3.4 macro for SPSS (Hayes, 2017).

CHAPTER 3

RESULTS

Bivariate correlations are presented in Table 1. There was a weak, positive association between the RewP to win PCA factor and depressive symptoms ($r(111) = .19$, $p = .045$), such that individuals with greater response to monetary win feedback tended to have greater depressive symptoms. There was also a moderate, positive association between RewP to loss and rejection sensitivity ($r(111) = .30$, $p = .001$), such that individuals with greater response to monetary loss feedback tended to have greater rejection sensitivity. As expected, there was also a moderate, positive association between depressive symptoms and rejection sensitivity ($r(118) = .42$, $p < .001$).

Table 1. Bivariate correlations between RewP to social and monetary reward using PCA peak activity, depressive symptoms, and rejection sensitivity.

Variables	*M* (*SD*)	1	2	3	4	5	6	7	8
1. RewP to accept PCA factor	5.13 (5.04)	--							
2. RewP to reject PCA factor	2.74 (4.65)	.59***	--						
3. Social RewP residual	0.00 (4.01)	.81***	.00	--					
4. RewP to win PCA factor	-1.02 (4.44)	.16	.22*	.05	--				
5. RewP to loss PCA factor	-3.50 (4.50)	.02	.15	-.08	.61***	--			
6. Monetary RewP residual	0.00 (3.53)	.18	.16	.12	.80***	.00	--		
7. Depressive symptoms	42.76 (12.27)	.03	.18	-.09	.19*	.15	.12	--	
8. Rejection sensitivity	10.13 (4.52)	-.01	.05	-.11	.08	.30**	-.12	.42***	--

Note: *$p < .05$, **$p<.01$, ***$p<.001$; PCA = principal component analysis; RewP = reward positivity

Next, two moderation analyses were conducted to investigate the relations between social and monetary RewP residual scores, rejection sensitivity, and depressive symptoms (see Table 2). In the social reward model, the social RewP residual score served as the moderator of the association between depressive symptoms and rejection sensitivity. In the monetary reward model, the monetary RewP residual score served as the moderator of the association between depressive symptoms and rejection sensitivity.

Table 2. Regression analyses testing the main and interaction effects of rejection sensitivity and RewP to social and monetary reward residual scores on depressive symptoms.

Predictor	Unstandardized *b (SE)*
RewP to Social Reward	
Rejection sensitivity	1.17 (0.23), $p < .001$
RewP residual	1.27 (0.63), $p = .046$
Rejection sensitivity X RewP residual	-.13 (0.05), Change $R^2 = .04$, $F(1, 113) = 5.93$, $p = .016$
Total model	$R^2 = .23$, $F(3, 113) = 11.13$, $p < .001$
RewP to Monetary Reward	
Rejection sensitivity	0.99 (0.24), $p < .001$
RewP residual	0.24 (0.72), $p = .740$
Rejection sensitivity X RewP residual	0.03 (0.07), Change $R^2 = .002$, $F(1, 109) = 0.19$, $p = .664$
Total model	$R^2 = .15$, $F(3, 109) = 6.48$, $p < .001$

Note: RewP = Reward positivity

The overall social reward model was significant, $R^2 = .23$, $F(3, 113) = 11.13$, $p < .001$. The significant main effect of rejection sensitivity on depressive symptoms was qualified by an interaction between rejection sensitivity and social RewP residual (see Figure 4A), $b = -0.13$, $SE = 0.05$, $t(113) = -2.44$, $p = .016$. Decomposing this interaction using simple slopes revealed that greater rejection sensitivity was associated with greater depressive symptoms at low (-1 *SD*), simple slope = 1.70, $SE = 0.31$, $t(113) = 5.44$, $p < .001$, and mean, simple slope = 1.17, $SE =$

0.23, $t(113) = 5.04$, $p < .001$, levels of social RewP residual. Simple slopes at high levels of social RewP residual were significant at a trending level, simple slope = 0.64, *SE* = 0.32, $t(113) = 1.97$, $p = .051$. To further examine this interaction, the effect of RewP on depressive symptoms was examined at low (-1 *SD*), mean, and high (+1 *SD*) levels of rejection sensitivity. A reduced social RewP residual was associated with more depressive symptoms only at high (+1 *SD*) levels of rejection sensitivity at a trending level, simple slope = -0.63, *SE* = 0.33, $t(113) = -1.93$, $p = .056$. The simple slopes at low (-1 *SD*) and mean levels of rejection sensitivity were not significant (*ps* = .155 and .856, respectively; see Figure 4B).

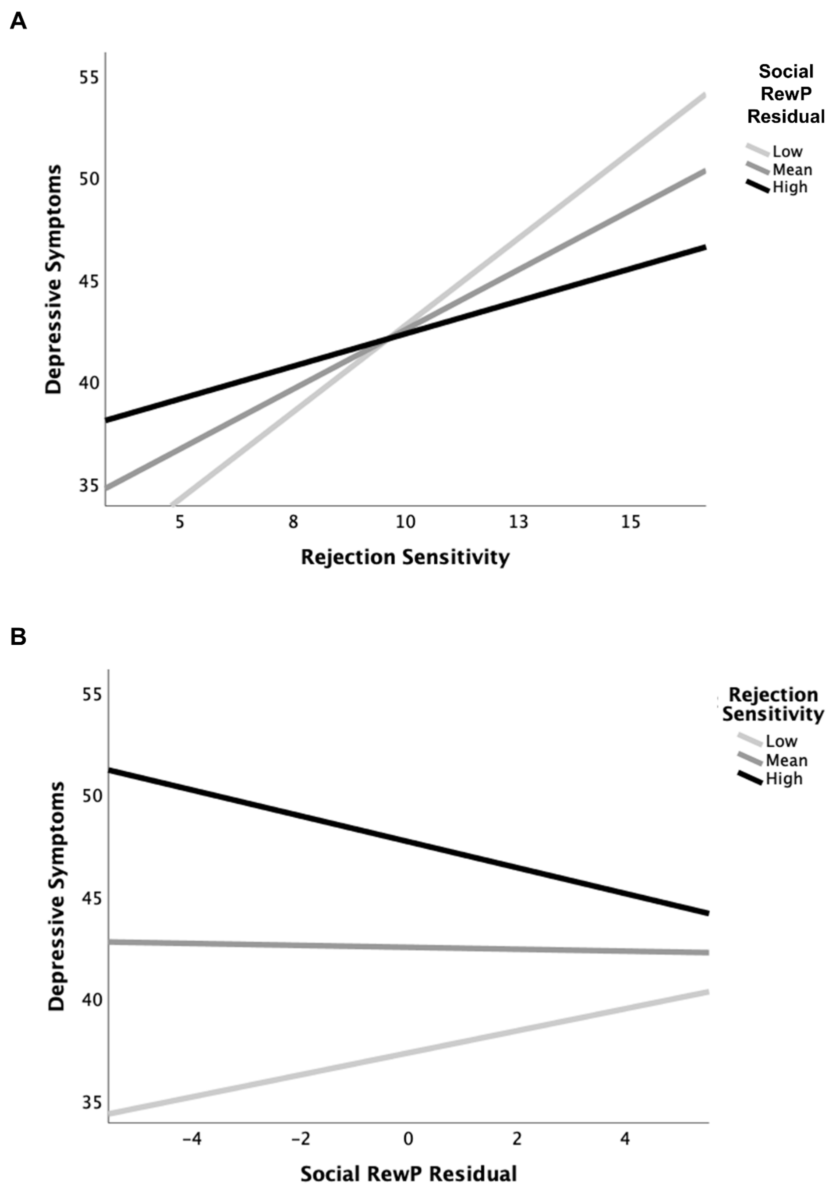

Figure 4. Simple slopes depicting (A) the relation between rejection sensitivity and depressive symptoms at low (-1 *SD*), mean, and high (+1 *SD*) levels of social RewP residual, and (B) the relation between social RewP residual and depressive symptoms at low (-1 *SD*), mean, and high (+1 *SD*) levels of rejection sensitivity.

The overall monetary reward model was significant, $R^2 = .15$, $F(3, 109) = 6.48$, $p < .001$. There was a significant main effect of rejection sensitivity on depressive symptoms. However, the interaction between rejection sensitivity and monetary RewP residual was not significant (p = .664).

CHAPTER 4

DISCUSSION

The current study examined the associations between social and monetary reward responsiveness, rejection sensitivity, and depressive symptoms in an unselected, emerging adult sample. Results of moderation analyses showed that greater rejection sensitivity was associated with greater depressive symptoms at low and mean levels of social reward responsiveness. Furthermore, reduced social reward responsiveness was associated with greater depressive symptoms at only high levels of social stress at a trending level. This moderation effect was only significant for social reward responsiveness and not response to monetary reward. Results of bivariate correlations revealed an unexpected weak, positive association between response to monetary win and depressive symptoms, as well as moderate, positive associations between response to monetary loss and rejection sensitivity and between depressive symptoms and rejection sensitivity.

These results provide important insight into the association between reward responsiveness and depression. Specifically, the combination of low social reward responsiveness and high rejection sensitivity was associated with greater depressive symptoms. Individuals that have reduced reward responsiveness may struggle with finding enjoyment in positive experiences and social activities (Setterfield et al., 2016). If these individuals are also highly sensitive to rejection and, thus, are more likely to expect, interpret, and react to rejection (Downey & Feldman, 1996; Leng et al., 2018; Romero-Canyas et al., 2010), they may be further disinclined to participate and find enjoyment in social activities, possibly leading to social withdrawal and isolation or negative self-perceptions. Through this pathway, these individuals may be more likely to develop depression. It is also possible that having high reward responsiveness may buffer against the potential negative impacts of having high rejection sensitivity on depression. Individuals high in rejection sensitivity but also high in reward responsiveness may still be more prone to experiencing negative emotions during potential rejection, but they may find more enjoyment and reward in their interactions in life, thus buffering against the potential negative impacts of being sensitivity to rejection and potentially protecting against the development of depressive symptoms. Additional work is needed to examine the causality and direction of the present findings to best characterize the relations between reward responsiveness, rejection sensitivity, and greater depressive symptoms.

The current findings also emphasize the importance of examining social reward responsiveness in understanding reward processing and pathways to the development of depression by identifying that the association between rejection sensitivity and depressive symptoms was related to social and not monetary reward. Previous work using monetary reward paradigms has examined the role that reward responsiveness plays in the development of depression (e.g., Kujawa, Hajcak, et al., 2019; Kujawa & Burkhouse, 2017; Nelson et al., 2016). However, results of this study and recent others (Ethridge et al., 2017; Pegg et al., 2019; Rappaport et al., 2019) provide evidence that other types of reward, particularly social reward, may be associated with unique neurophysiological reward processing. Work examining monetary rewards alone may not detect interactions between important precursors to depression and psychopathology. It is important to examine potential differences in reward processing to better understand the potential impact these differences have on trajectories of depression.

Of note, the neurophysiological response to monetary reward presented as an overall negative-going component in the PCA results that was relatively more positive for win versus loss feedback. RewP is typically a positive-going component in which the ERP wave is more positive in response to win compared to loss feedback (Proudfit, 2015). There is debate in the literature regarding whether the component RewP is best characterized by an overall positivity, negativity, or two overlapping components (i.e., a negativity for loss and positivity for wins). Traditionally, research has focused on a component called the feedback negativity or feedback-related negativity, which is a relative negativity for negative outcomes compared to positive outcomes at frontocentral sites that peaks about 300 ms following feedback presentation (Foti et al., 2011; Gehring & Willoughby, 2002; Hajcak et al., 2006; Santesso et al., 2011). Others have argued that there are two separate overlapping components, the N200 and the feedback error-related negativity, however, other work suggests that the two components are indeed one positive-going deflection (Holroyd et al., 2008). Prior PCA studies examining a simple guessing reward task, in which participants guessed where a prize was located on the screen and were randomly assigned monetary win and loss feedback, have not found evidence for a feedback negativity or overlapping components (Foti & Hajcak, 2009; Kujawa et al., 2018; Rappaport et al., 2019). These studies instead found that a positivity to rewards relative to losses best characterizes neural response to reward in that task (Foti & Hajcak, 2009; Kujawa et al., 2018; Rappaport et al., 2019). While components have been identified and examined using the ERP version of the MID task using the more traditional method of time window averages (B. Novak et al., 2016; K. D. Novak & Foti, 2015), no previous research has investigated components observed in response to reward feedback on the MID task using PCA prior to this study. It is possible that the resulting component consistent with RewP on MID was an overall negativity because negative feedback may be more salient on reward tasks that are more performance-based, such as MID, compared to the guessing reward task previously examined with PCA. Additionally, Dien (2012) has noted that the sign of each factor generated by ERP PCA Toolkit should be interpreted with caution. It is possible that RewP is still an overall positive-going component in the observed EEG data and was assigned a negative factor sign by the program, which is supported by the ERP waveform for the task in Figure 2. Despite the component from the PCA being an overall negativity, the win condition was still relatively more positive compared to the loss condition in the component identified as RewP, and using a residual score in the present analyses for both tasks should prevent the overall negative scores on the monetary reward task versus overall positive scores on the social reward task from impacting results, meaning the results represent neurophysiological response to reward and are not based on the difference in presentation of RewP in the monetary reward task compared to previous work. Future research is needed to replicate the present findings in a larger sample using PCA.

A second unexpected result was a positive but weak association between neurophysiological response to win feedback and depressive symptoms. While depressive symptoms have been found to be negatively associated with neurophysiological response to win feedback (Kujawa, Hajcak, et al., 2019), this finding is consistent with other work showing that symptoms of consummatory anhedonia were positively associated with neurophysiological response to win and loss feedback using a guessing reward task (Chen et al., 2018). The weak positive association found in this work and the present study suggests that these relations may be complicated, and this finding should be interpreted with caution. Additional work is needed to examine specific symptoms of depression and their relations to neurophysiological response to reward, including both monetary and social rewards, to better understand previously found associations that may predispose individuals to developing depression.

There are several limitations of the present study worth noting. A cross-sectional design was employed in this study and, thus, the causality and direction of results are unable to be determined. It will be important to examine these relations in a longitudinal sample to better understand timing of the development of reduced reward responsiveness, high rejection sensitivity, and onset of depressive symptoms to be able to better target vulnerabilities for depression through intervention before symptoms develop. Additionally, despite 15.0% of the sample meeting the self-report cutoff for major depressive disorder (Stasik-O'Brien et al., 2019), the present sample was unselected and non-clinical. Future studies should investigate the relations between vulnerabilities and depressive symptoms in a clinical sample to examine whether the present results generalize to clinical populations. We also used a self-report measure of current depressive symptoms. Future work should use an interview-based clinical assessment of symptoms to confirm diagnoses and potential comorbidities.

Despite these limitations, the present study is the first to examine the difference in associations between neurophysiological social and monetary reward responsiveness on rejection sensitivity and depressive symptoms in an emerging adult sample. These findings emphasize the importance of considering different types of reward in understanding the implications of reward processing on depression. Results also suggest a pathway by which social reward responsiveness may interact with rejection sensitivity to potentially increase the likelihood of depression. After further investigation into the causality and direction of these effects, it may be possible to design an intervention that targets vulnerabilities to depression prior to symptom onset and identify individuals most at risk.

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