

Examining Rumination and Neurophysiological Measures of Emotional Reactivity and
Regulation in Depressed Adolescents

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Abstract

Depression is a leading cause of disability around the world and there is a need to better understand its core neural mechanisms in order to improve targeted treatment. The goal of the current study is to investigate the neural mechanisms and time course of emotion and associations with individual differences in rumination in a sample of depressed adolescents. Rumination is the repetitive and focused attention on one's distress and involves the inability to produce effective solutions to one's problems, and this negative thought process may prolong or worsen depressive symptoms. The effects of rumination on neural processing of emotionally salient stimuli can be examined using electrophysiological measures. In this study, 55 depressed adolescents completed an emotion regulation task during which they were asked to observe 25 sad and 25 neutral images. Participants were instructed to either react as they normally would or reduce their emotional response to the pictures while electroencephalogram (EEG) data was recorded. The late positive potential (LPP), which reflects sustained attention to stimuli, was measured in order to understand how and when individuals allocate their attention to negative stimuli. Results showed that higher levels of depressive rumination correlated with reduced LPPs during reappraisal for both middle (1000-3500ms) and late (3500-6000ms) time windows. Reactivity indexed by the LPP was higher in both reappraise and look conditions compared to the neutral condition. Additionally, the difference for the reappraise condition compared to the look condition was trending significant in the expected direction, where LPP magnitude was relatively decreased during reappraisal compared to passive viewing of the images. Such insight into these stages of emotion processing may help target interventions in reducing ruminative thought processes in certain subgroups of depressed populations.

Introduction

Depression is a debilitating psychological disorder in which affected individuals experience persistent depressed mood, loss of interest in activities, and/or loss of pleasure in daily life, along with associated symptoms including fatigue, sleep and appetite changes, trouble concentrating, hopelessness, and thoughts of death. Major depressive disorder (MDD) impacts about 7% of the adult population in the United States at any given time and rates increase dramatically in adolescence and young adulthood, with approximately 25% of youth affected by the disorder at some point in life (“Major Depression”, 2016). Depression has a devastating impact on individuals’ general functioning. Adolescent depression in particular has persistent effects on functioning across the lifespan (Mendelson & Tandon, 2016) and alterations in cognitive and emotional reactivity may be driving some of these impairments. Depression is characterized not just by depressed mood, but also by changes in cognitive processing of emotions at the neural level (Wisco et al, 2014). New research has focused on how individual differences in neural responses to emotional stimuli impact the development and maintenance of depression, and how a focus on identifying these individual differences may help improve treatment for depression. Specifically, depression is characterized both by impairments in emotion regulation and by tendencies to ruminate, and the current study examined the association between these processes in a clinically depressed adolescent sample.

Emotion Regulation in Depression

Emotion regulation (ER) is the way in which people respond to emotional stimuli in their environments and involves the ability to meet the demands of an emotional experience in a flexible and appropriate manner. Examples of positive ER strategies include acceptance, attentional deployment, distraction, and positive reappraisal (Aldao et al, 2009). Reappraisal

involves thinking about a negative emotional situation in a more positive way and leads to improvements in coping with negative emotions. Reappraisal may involve changing the emotional experience of a situation by changing the personal relevance of the stimulus or reinterpreting the emotions, actions, and outcomes of the situation. It begins to exert its effect later in the time course of emotional processing after information has been appraised or evaluated (Moser et al, 2009).

Emotional dysregulation is prevalent in most forms of psychopathology. Depressed individuals often exhibit deficits in the ability to regulate their emotions to fit the needs of their situations and environments, and they tend to lack positive emotion regulation strategies that may help shorten and/or diminish depressive episodes (Nolen-Hoeksema et al, 2008). Negative cognitive processes such as rumination lead to a negative psychological state in depressed individuals, so that they often have difficulty responding appropriately in certain situations.

Rumination in Depression

Rumination, the act of repetitively thinking about a problem with oneself or with a situation in life, leads to unwanted negative intrusive thoughts and negative cognitive biases, low self-esteem, and low social support as a result of impaired social relationships (Nolen-Hoeksema et al, 2008). It has been shown to be a factor in the development and maintenance of depression, as it impairs thinking, problem solving and behavior as well as social relationships, associations that are thought to be due in part to impairments in emotion regulation (Nolen-Hoeksema et al, 2008). Nolen-Hoeksema's response styles theory argues that a ruminative response style prolongs distress in depression because individuals think about problems repetitively while failing to come up with solutions and attribute negative situations to their inability to control or handle the situations. Depressed individuals tend to orient themselves toward negative emotional

stimuli and view themselves as inadequate and worthless, with no hope for the future. People with a ruminative response style also tend to display negative interpretation biases. Current research on neural mechanisms has furthered our understanding of emotion regulation strategies. Rumination as a cognitive process has been identified in depression but its neural underpinnings are not yet clearly defined.

Neural Measures of Emotion Regulation and Rumination

Studies analyzing neural measures of rumination using electroencephalogram (EEG) and functional magnetic resonance imaging (fMRI) data have shown that impaired emotion regulation abilities as a result of the use of rumination lead to repetitive negative thinking, inability to appropriately react to situational stimuli, and impaired reactions to social stimuli. In a recent study, 26 adolescents in remission from depression and 15 healthy control adolescents completed self-report measures of depression and rumination and were also assessed by a clinician. Participants completed an fMRI rumination induction task to assess patterns of neural activity during rumination and during a distraction phase. Results demonstrated that adolescents with remitted major depressive disorder increased recruitment of brain regions involved in visual and emotion processing, such as the hippocampus and the occipital gyrus. Activation in these areas of the brain was positively correlated with increased self-report ratings of depressive and ruminative symptoms (Burkhouse et al, 2017).

In another study, researchers aimed to examine the neural bases of rumination within the context of emotional control in a nonclinical population in order to establish a neural model of the tendency to ruminate. They found that the highly ruminating group showed increased activation of the left temporal lobes and decreased activation of the dorsolateral prefrontal cortex (DLPFC) and were able to confirm that the emotional control circuit is involved in rumination.

Ruminators are more emotionally reactive to negative stimuli, and the researchers concluded that the top-down emotional circuit (from left DLPFC to left temporal lobe) is dysfunctional and is highly related to rumination (Ferdek et al, 2016). These examples of research on neural correlates of rumination show that it leads to patterns of dysfunctional thought processes. A deeper understanding of impaired cognitive processes in specific individuals has important implications for enhancing treatments and therapy for depression.

The Late Positive Potential (LPP) as a Measure of Emotion Regulation

Not all depressed individuals are ruminators, and a refined understanding of the subtypes of depression would allow for more targeted interventions adapted to the individual. Interest in the study of ER strategies has grown as researchers increasingly recognize the impact that appraisals of situations have on the moods and thought processes of depressed individuals. A common method used to study ER is the presentation of positive or negative images and the assessment of individual neural responses to the emotional stimuli, with explicit instructions given to participants to downregulate their emotional responses (typically through reappraisal). Reappraisal has been shown to be effective at promoting emotion regulation processes that decrease the negative impact of unpleasant stimuli (Moser et al., 2014). One study demonstrated that participants scoring high on depressive symptoms showed increased emotional arousal to negative stimuli and decreased arousal to positive stimuli. This shows that even at preclinical stages, implicit emotion processing is impacted by the level of depressive symptoms (Bocharov et al, 2017).

Compared to fMRI, event-related potentials (ERPs) derived from EEG have limited spatial resolution but can provide important insights into the time course of emotional reactivity and regulation. ERPs are brain signals with a millisecond temporal resolution that reveal the

neural mechanisms associated with how people process information over time (Moser et al, 2014). They are small voltages generated as a result of brain responses to a discrete stimulus that provide an objective measure of emotional reactivity and regulation. ERPs may be particularly well suited for examining the time course of processing of emotional stimuli in individuals varying in tendencies to ruminate.

In particular, the late positive potential (LPP), a scalp-recorded ERP, reflects sustained attention to emotional stimuli and therefore has been identified as a possible neural marker of ER (Dennis and Hajcak, 2009). LPP responses to stimuli can be divided into earlier and later stages of processing. The LPP, which reaches its maximum amplitude between 300 and 800 milliseconds after the onset of a stimulus, is a useful measure because many studies have shown that it is enhanced for highly arousing (pleasant or unpleasant) images (Moser et al, 2006). The magnitude of the LPP is enhanced if the emotional content of a stimulus is more salient or arousing. Attenuated LPP results suggest dysfunction in the modulation of later stages of socio-emotional processing and blunted LPP responses have been considered as a potential vulnerability marker for depression, reflecting tendencies to disengage from emotional changes in the environment and inhibiting adaptive responses (Grunewald et al, 2018; Kujawa et al, 2015). Essentially, the LPP allows for insights into the neural underpinnings of cognitive emotion regulation as it provides information about emotional responses to stimuli over a specific course of time. Positive ER strategies like reappraisal are associated with the ability to modulate the LPP in response to emotional images (Moser et al., 2006). The LPP appears to be an important index of abnormalities in emotional regulation and reactivity but little work has examined the effects of specific cognitive styles like rumination on the LPP. Existing literature has shown that rumination is associated with a greater LPP magnitude during an emotion

regulation task (Lewis et al., 2015; Webb et al., 2017; Whiteman & Mangels, 2016), but more work is needed on individual differences in rumination. Given that ruminative responses are thought to impair the ability to effectively regulate and respond to emotions, it is possible that individual differences in rumination correspond with the LPP in an emotion regulation task, but to our knowledge, no prior work has tested this possibility.

The current study aimed to address the relationship between the LPP during an emotion regulation task and rumination in depressed adolescents. We hypothesized that individuals high in rumination may exhibit alterations at earlier stages of emotion processing, reflecting problems with immediate reactivity, and/or may have trouble with later disengagement or reappraisal of emotional stimuli.

Method

Participant Characteristics

Participants were part of an ongoing study of neural predictors of cognitive behavior therapy (CBT) response in adolescents with depression in the Mood, Emotion, and Development Lab directed by Dr. Kujawa in the Department of Psychology and Human Development. Participants were recruited from research participant email lists, VU and community psychiatric and pediatric clinics, social media, Nashville public schools and the surrounding communities. Advertisements were placed on websites and social media and sent to members of the university, doctors' offices, schools, and community centers. This broad recruitment strategy attempted to ensure that participants were diverse in race/ethnicity, sex, and age. EEG data were available for a sample of 55 adolescents with current depression with a mean age of 15.85 years ($SD = 1.51$; range: 14 to 18 years). The final sample was 64% female and 82% Caucasian, 3.6% African American, 3.6% Asian, 7.3% Latinx/Hispanic, and 3.6% Other/Mixed race. Youth taking

antipsychotic medications or mood stabilizers or with intellectual/developmental disabilities, lifetime schizophrenia, psychosis, mania, or severe current suicidality were excluded from the study. A current MDD or persistent depressive disorder (PDD) diagnosis was required for inclusion. At the time of intake, 57.4% of participants had current MDD and 72.2% had current PDD with or without intermittent major depressive episodes (past MDD = 27.8%; past PDD = 16.7%)., indicating that most of the sample experienced chronic depression. All participants completed self-report measures of rumination and depressive symptoms, as well as the EEG emotion regulation task during their visit in the laboratory.

Procedure

Informed consent was obtained from parents of minors and participants who were 18 years old. Assent was obtained from minor participants. After the participants and/or parents completed consent forms in the laboratory, the participants were led to a separate room to complete questionnaires and the EEG task.

Measures

Clinical depression.

All participants met the criteria for a current depressive disorder as outlined in the DSM-V version of the Kiddie Schedule for Affective Disorders and Schizophrenia, Present and Lifetime Version (KSADS-PL; Kaufman, 2016). This assessment, in addition to the Clinical Global Impression Scale (Guy, 1976) to determine disorder severity, was completed at the initial screening visit for the study by Masters-level interviewers or graduate students, under the supervision of a licensed clinical psychologist (Dr. Kujawa). At intake, participants also completed the Ruminative Responses Scale (Nolen-Hoeksema & Morrow, 1991) among other measures, including the Mood and Feelings Questionnaire to measure depressive symptoms

(Robin & Foster, 1989). The MFQ was included as a covariate in regression analyses to test the effects of rumination on the LPP beyond the effects of depression symptom severity.

Ruminative Responses Scale

The RRS is a useful self-report tool in researching response styles in depressed individuals. This measure describes different aspects of rumination, rated on a four-point scale: 1-Almost Never, 2-Sometimes, 3-Often, 4-Almost always. The questionnaire provides scores for Brooding (“a passive comparison of one's current situation with some unachieved standard”), Reflection (“a purposeful turning inward to engage in cognitive problem solving to alleviate one's depressive symptoms”) and Depression (“the repetitive and passive thinking about one's symptoms of depression and the possible causes and consequences of these symptoms”) categories (Treyner, et al., 2003; Nolen-Hoeksema, 2004) as well as total rumination. A reflective rumination score was missing for one participant.

EEG Assessment

Participants completed the EEG assessment in our laboratory. Data was collected and processed using a 32-channel BrainProducts actiCHamps System and BrainVision Recorder software (Munich, Germany). Once EEG caps were in place, we recorded resting EEG data for six minutes. Then, participants completed a series of tasks in a counterbalanced order, including the emotion regulation task which took approximately 15 minutes. The emotion regulation task required participants to view 25 sad (e.g. crying people) and 25 neutral images in a pseudorandom order. Sad images were presented twice, once with the instructions to simply look at the images and respond naturally, and once with the instructions to decrease their emotional responses to the images. The pictures were from the International Affective Picture Stimulus (IAPS) set (Lang et al., 2008). We first provided participants examples of how to modulate their

emotional responses, such as reappraising the pictures, and participants completed a practice block of 4 trials. Next, participants completed the full task with the instructions “LOOK NEUTRAL”, “LOOK NEGATIVE”, or “DECREASE NEGATIVE” presented on the computer screen prior to an image presented for 6 seconds. After each trial, participants were asked to rate the intensity of their emotional reactions to the stimuli. The scale for the strength of the emotional reaction was 1 (very weak) to 7 (very strong).

EEG data were processed offline using BrainVision Analyzer software, re-referenced to the linked mastoid reference, filtered at .01 to 30 Hz, and corrected for eye movements. Artifacts were removed using semi-automated procedures. Averages were computed for each condition and baseline corrected to the 200ms preceding stimulus onset. The LPP was scored in three time windows (300-1000ms, 1000-3500ms, 3500-6000ms) at parietal electrode sites (Pz, P3, P4), consistent with prior work (Hajcak et al., 2010). Primary analyses focused on relative responses on decrease/reappraise vs. look trials for earlier and later ERPs to capture neural responses associated with explicit attempts to regulate emotional responses.

Results

Descriptive statistics and bivariate correlations for the sample are presented in Table 1. Given this was a clinical sample, depressive symptoms scores were high, as expected. Approximately one third of the sample had a comorbid anxiety diagnosis. Compared to other studies using the RRS, total rumination scores in this clinical sample ($M = 57.15$, $SD = 15.2$) were consistent with existing literature (Zhang et al., 2020: $M = 57.42$, $SD = 11.26$; Hasegawa et al., 2018: $M = 51.48$, $SD = 13.38$). The bivariate correlations were consistent with our hypotheses and previous research, such that each type of rumination was associated with higher levels of depressive symptoms. Additionally, there were trend level correlations between

depressive rumination and the LPP, such that higher levels of depressive rumination correlated with reduced LPPs during reappraisal for both the middle and late time windows.

Effect of Reappraisal on Neurophysiological Responses

A 3 (time: 300-1000ms, 1000-3500ms, 3500-6000ms) x 3 (condition: reappraise, look, neutral) repeated-measures ANOVA was first used to analyze differences in neural activity at parietal sites to emotional images during reappraisal compared to passive viewing. The main effect of time $F(1, 54) = 52.550, \eta^2 = .493, p < .001$ was significant. The overall magnitude of the LPP decreased from the earliest time window (300-1000ms) to the latest time window (3500-6000ms), $F(1, 54) = 57.625, \eta^2 = .516, p < .001$, and from the earliest time window (300-1000ms) to the middle time window (1000-3500ms), $F(1, 54) = 61.176, \eta^2 = .531, p < .001$. The difference in the decrease between the middle time window (1000-3500ms) and the latest time window (3500-6000ms) was approaching significance, $F(1, 54) = 3.925, \eta^2 = .068, p = .053$.

The overall main effect of condition was significant $F(1,53) = 12.484, \eta^2 = .320, p < .001$, such that reactivity indexed by the LPP was higher in both the reappraise, $F(1,54) = 8.801, \eta^2 = .140, p = .004$, and the look, $F(1,54) = 25.326, \eta^2 = .319, p < .001$, conditions compared to the neutral condition. Additionally, the difference for the reappraise condition compared to the look condition was trending significant, $F(1,54) = 3.561, \eta^2 = .062, p = .065$, in the expected direction, such that LPP magnitude was relatively decreased during reappraisal compared to passive viewing of the images. There was no significant interaction between time and condition ($p = .504$).

Rumination as a Predictor of Neurophysiological Measures of Reappraisal

Finally, we tested the effects of the three styles of rumination (depressive, brooding, reflective) on the LPP amplitude on reappraisal trials, controlling for the LPP on look trials and

depressive symptom severity (Table 2). There was a significant negative association between depressive rumination and the LPP during reappraisal in the late time window ($p = .022$), such that higher depressive rumination was associated with lower LPP. The other types of rumination were not significant. Results are presented in Table 2.

Discussion

The specific aims of the present study were to characterize the time course of emotional reactivity and regulation at the neural level in depressed adolescents and to assess whether rumination impacts the magnitude of the LPP during reappraisal over a specific time course. Our examination of emotion processing using the LPP component informs understanding of the neural mechanisms of rumination and whether depressed adolescents high in rumination exhibit difficulties at each stage of processing, specifically during cognitive reappraisal, which is a potential target for intervention.

Overall LPP Magnitude and Condition

Results showed that the overall magnitude of the LPP significantly decreased from the earliest time window to both the middle and the latest time windows. Additionally, the magnitude of the LPP was relatively decreased in the reappraise condition as compared to the look condition at a trend level. This finding suggests that neural reactivity is reduced for reappraise, as was expected. On average, depressed adolescents are able to downregulate their emotional responses to dysphoric images when prompted to do so. The trend level finding compared to other studies with significant effects for reappraisal on the LPP could be due to a clinically depressed sample, whereas other studies used non-clinical samples. Thus, even though the findings suggest that depressed adolescents are able to downregulate their response, their reappraisal attempts may not be as effective or may be more impaired compared to healthy

adolescents. Other studies of nonclinical samples examining the relationship between LPP magnitude and reappraisal have shown that reappraising is associated with decreases in parietal arousal-related neural activity, with a reduction in LPP magnitude specifically (Moser et al., 2014; Hajcak & Nieuwenhuis, 2006). In addition, existing literature suggests that a brief description prior to the presentation of a stimulus (that is neutral or more negative) can modulate neural response to emotional stimuli, providing evidence for both the instruction of “reappraise” as well as for the use of the reappraise strategy (Foti & Hajcak, 2008).

Rumination and the LPP

Results also indicated that there was a significant association between depressive rumination and the LPP during reappraisal in the late time window. This association was the opposite of what was expected because it indicated that higher depressive rumination levels were associated with more reduced LPPs during reappraisal while controlling for LPP on look trials, which is thought to index *better* emotion regulation. Higher levels of depressive rumination were associated with reduced LPP amplitudes during reappraisal, which is inconsistent with existing literature that has shown that rumination is associated with a greater LPP magnitude during an emotion regulation task (Lewis et al., 2015; Webb et al., 2017; Whiteman & Mangels, 2016). A potential explanation for this result is that the amplitude of the LPP has been shown to be reduced under high cognitive load (MacNamara et al., 2011). Therefore, it is possible that as self-focused depressive rumination increases, the cognitive demand is increased, and the LPP to external emotional stimuli would decrease as observed in the present study.

Another potential explanation for the negative association between depressive rumination and reduced LPP during reappraisal is that comorbid anxiety disorders present in our sample may have affected the results. Prior research has shown that the LPP is blunted in depression but

heightened in anxiety (Kujawa et al., 2015). Approximately one third of the sample in this study had a comorbid anxiety diagnosis; since research has shown that rumination has opposing associations with anxiety and with depression (MacNamara et al., 2016) indexed by alterations in the LPP, an anxiety diagnosis for participants may have confounded the results.

Additionally, a possible explanation for this association may be that the results are due to collinearity, in that each of the subscales of rumination were highly correlated. This may have resulted in unstable parameter estimates with higher standard errors. However, similar patterns were apparent with bivariate associations, which suggests that collinearity is not the primary factor driving this finding.

Finally, it is possible that the clinical population of depressed participants in this study tend to ruminate on their own problems which generally blunts reactivity to external stimuli (Imbault & Kuperman, 2018; Schiller et al., 2013). Therefore, the association between higher rumination levels and lower LPP magnitude during reappraisal trials can potentially be explained by the fact that depressed individuals, especially those who engage in self-focused rumination, have generally blunted reactivity to stimuli.

Clinical Implications

The findings of the present study support the notion that cognitive reappraisal is an effective mechanism for intervention (Compas et al., 2014) and that the LPP provides an objective, reliable marker of emotion regulation ability (Moran et al., 2013) that could be used to index treatment response. The results of the ANOVA analyses indicated that the emotion regulation task used in this study is effective for measuring neural responses during emotion regulation for further consideration in future research on mood disorders.

Limitations and Suggestions for Future Research

A few limitations of this present study should be noted. First, this study was completed using a clinical sample. Characteristics of this clinical population, such as possibly general blunted reactivity to outside stimuli, may limit generalizability of the present findings to other diagnoses or healthy populations. Additionally, there is a limitation to assessing rumination at the self-report level, as it is unclear whether participants were ruminating or not during the EEG task since rumination was not assessed at the same time as the task was administered.

Future studies can extend these study methods to other populations, such as remitted depressed adolescents or adolescents without depression but at high risk due to parental history (Kujawa et al., 2014). Future studies can also examine gender differences in rumination in relation to LPP magnitude over the course of the EEG task. Regarding the depressed adolescent population, current research suggests that there are significant sex differences in the development of ruminative response styles and internalizing symptoms of depression. Girls tend to be at greater risk of developing ruminative styles than boys, and generally experience greater exposure to interpersonal dependent stress (Alloy et al., 2016; Hamilton et al., 2015). The present study included both genders and did not examine gender differences.

Conclusion

The current findings highlight the utility of the emotion regulation task and the use of neurophysiological measures, specifically ERP measures, to assess emotion reactivity and regulation, and how these are impacted by ruminative thought processes. These findings provide further support for the emotion regulation strategy of reappraisal as useful for reducing neural activity to emotionally salient stimuli. Additionally, our study supports the use of neural markers

such as the LPP as objective measures for assessing emotion regulation ability, with the potential for extension to treatment studies.

The purpose of this study was to provide insight into the effects of rumination on neural processing of emotional stimuli in a sample of depressed adolescents and help to understand how this insight can translate to identifying individuals who would most benefit from therapies targeting rumination. Future research is needed to better understand whether rumination impacts the LPP due to increases in cognitive load, because it is self-focused and distracts from stimuli, or if the associations between rumination and the LPP are different across different populations (i.e. anxious adolescents). An important domain of research still to be investigated within the field of ER is mapping rumination on to brain function in order to identify specific neural targets of cognitive-behavioral therapy (CBT), as well as examining how CBT can be enhanced with a focus on encouraging positive ER strategies. The most important goal for this field of research on rumination is to apply developing knowledge of dysfunctional thought processes and neural correlates to treatments for depression. If we better understand how individuals ruminate over a specific time course using neural measures such as those used in this study, we can focus treatments to be more effective in reducing this negative cognitive process. Understanding the effects of emotion across time and individual neural responses to emotional stimuli will help us better understand how negative emotions are translated to regular life outside of the laboratory.

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Table 1. *Descriptive Statistics and Bivariate Correlations (N=55)*

Variables	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Depressive symptoms score	33.65	14.06	-												
2. Depressive rumination score	32.75	8.77	.597***	-											
3. Brooding rumination score	12.65	4.1	.554***	.730***	-										
4. Reflective rumination score	11.81	3.84	.509***	.757***	.638***	-									
5. LPP Reappraise Early	6.36	4.07	0.108	0.046	0.048	0.015	-								
6. LPP Reappraise Mid	2.64	4.41	-0.127	-.226^	-0.177	-0.116	.306*	-							
7. LPP Reappraise Late	2.42	4.89	-0.112	-.259*	-0.151	-0.128	.309*	.850***	-						
8. LPP Look Early	7.14	4.4	0.145	0.112	0.112	0.049	.855***	0.203	.242^	-					
9. LPP Look Mid	3.76	3.85	-0.016	-0.053	-0.1	-0.114	.522***	.328*	.488***	.700***	-				
10. LPP Look Late	3.08	4.49	-0.03	-0.008	-0.024	-0.043	.500***	.375**	.581***	.649***	.881***	-			
11. LPP Neutral Early	4.64	3.67	.164	.210	.117	.203	.660***	.180	.100	.704***	.404**	.430**	-		
12. LPP Neutral Mid	1.54	3.15	-.059	.122	-.113	.064	.256^	.418**	.325*	.340*	.452**	.481***	.630***	-	
13. LPP Neutral Late	0.97	3.88	-.082	.142	-.038	.049	.207	.325*	.359**	.183	.330*	.501***	.388**	.761***	-

^ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 2. Regression analyses testing the effects of rumination subscales on the LPP during reappraisal controlling for LPP on look trials and depressive symptoms.

	Reappraise LPP early (300-1000ms) Unstandardized b(SE)	Reappraise LPP mid (1000-3500) b(SE)	Reappraise LPP late (3500-6000) b(SE)
Step 1: $F(R^2)$	69.65 (.732)	3.72 (.127)	13.71 (.350)
Depressive symptoms	-.01 (.02)	-.041 (.041)	-.035 (.040)
Look LPP	.79 (.07)***	.380 (.150)*	.632 (.123)***
Step 2: $F(R^2)$	26.79 (.736)	2.02 (.173)	7.23 (.429)
Depressive symptoms	.007 (.028)	-.005 (.053)	.021 (.049)
Look LPP	.798 (.070)***	.386 (.152)*	.644 (.119)***
Rumination			
Depressive	-.026 (.063)	-.165 (.121)	-.264 (.112)*
Brooding	-.055 (.116)	-.051 (.222)	.041 (.204)
Reflective	.040 (.124)	.240 (.239)	.261 (.219)
Final model $R^2 = .43$ ***			

^ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 1. Grand average ERP waveforms for look, reappraise, and neutral conditions at Pz, P3, and P4 parietal electrode sites.

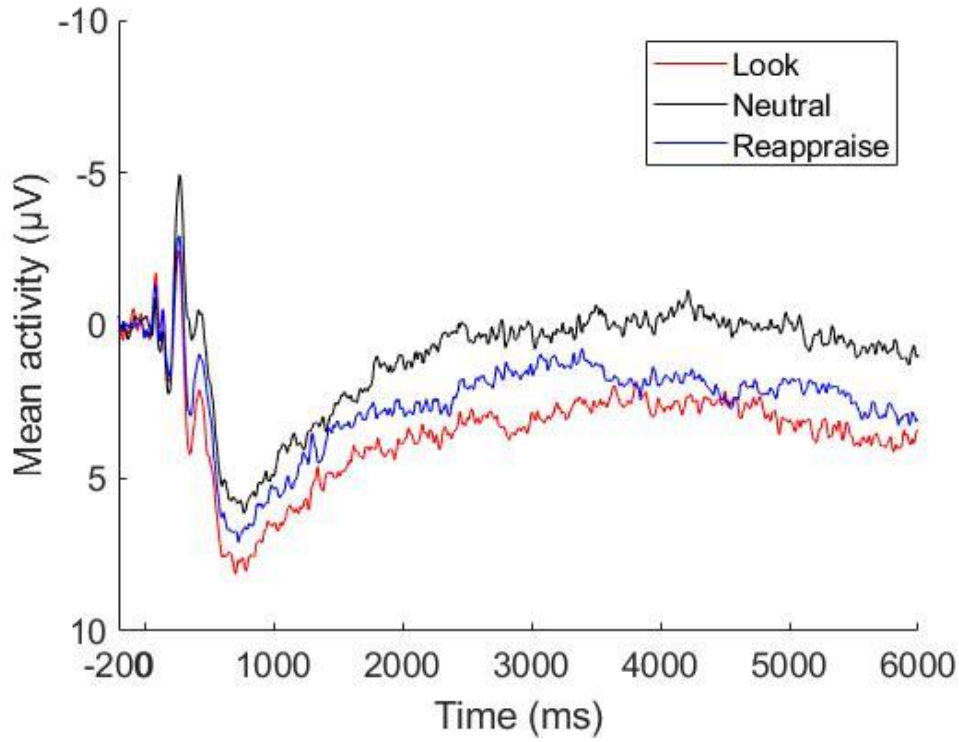


Figure 2. Scalp distributions depicting neural responses to reappraise minus look for early, mid, and late LPP.

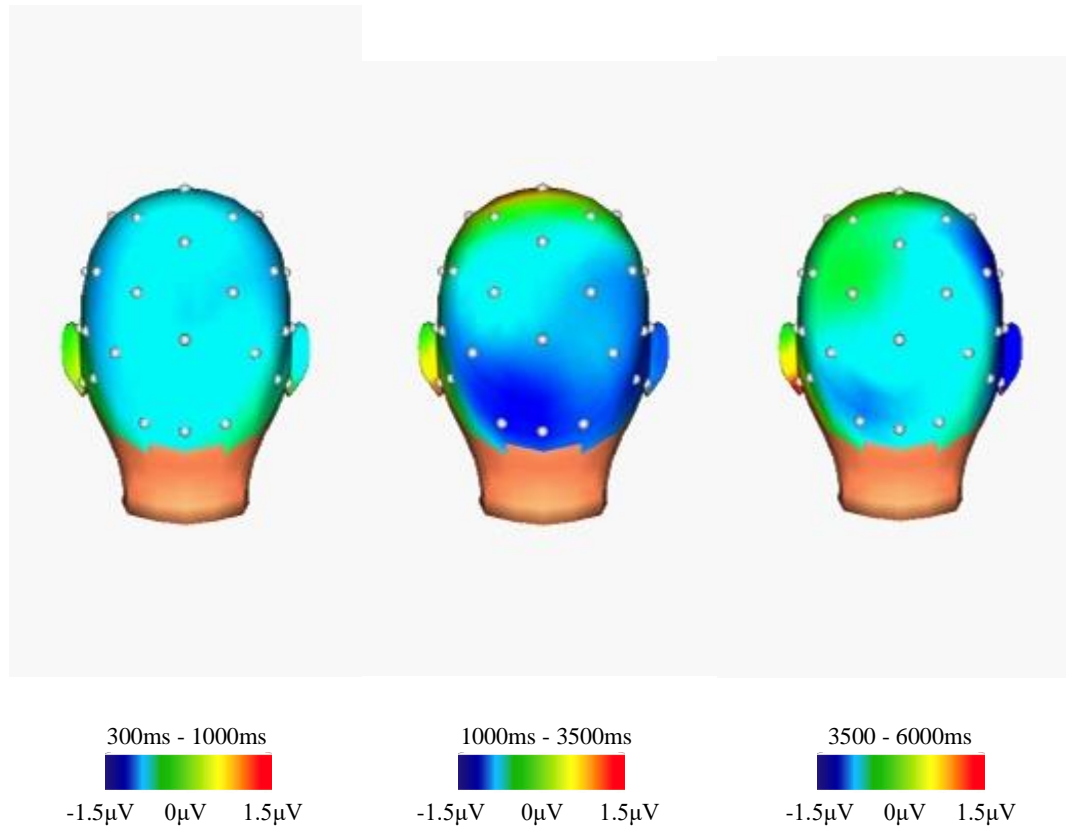


Figure 3. Depressive rumination predicting the LPP during reappraisal, controlling for the look condition.

