

Negative bias for sad imagery in depression: An ERP study

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Abstract

Individuals with depression experience more negative imagery and less vivid positive imagery, and the late positive potential (LPP) is considered as a viable biomarker for negative attentional and memory biases in depression; however, the LPP response to emotional imagery in depressed individuals remains unclear. This study aims to investigate neural response to emotional imagery in depressed individuals. ERPs were recorded from 40 depressed participants and 44 healthy controls during the encoding-imagery task. Depressed participants scored significantly lower in the valence rating of sad and neutral imagery compared to healthy participants. Importantly, the LPP amplitudes to sad imagery in depressed participants were significantly larger than healthy controls, particularly in the middle (800-1,400 ms) and late time windows(1,400-2,000 ms). Furthermore, depressed individuals exhibited significantly higher LPP amplitudes for sad imagery compared to happy imagery, whereas healthy participants showed the opposite pattern. The present study provides evidence that depressed individuals display abnormal electrophysiological reactivity to sad imagery, which offers a new perspective for understanding the mechanisms underlying depression.

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Keywords: Depressed individuals, healthy controls, event-related potentials (ERPs), late positive potential (LPP), and emotional imagery

1.Introduction

Individuals with depression experience more intrusive negative imagery and less vivid positive imagery (Holmes et al., 2016; Weßlau & Steil, 2014). Abnormal emotional imagery may amplify other maladaptive processes in depression, and play an important role in the maintenance and development of depression (Holmes et al. 2009, 2016). Examining imagery biases in depression provides valuable insights into the mechanisms of this disorder (LeMoult & Gotlib, 2019). Moreover, depressed individuals have mood-congruent internal mental representations or schemas (Beck, 1967), and have been supported by numerous studies exploring the neural response of depressed individuals to external emotional stimuli (Benau et al., 2019; Zhou et al., 2021). However, emotional imagery, a mental representations of imagined emotional events or stimuli, might more closely mirror the experiences of individuals with mood disorders (Bauer & MacNamara, 2021). Therefore, exploring the neural correlates of emotional imagery in depressed individuals may contribute to further understand the underlying mechanisms of depression.

The late positive potential (LPP), an event-related potential (ERP) beginning approximately 300-400 ms following stimulus presentation at centroparietal electrodes, is a reliable neural indicator to emotional stimuli (Hajcak & Foti, 2020; Hajcak et al., 2010; Moran et al., 2013). The LPP is sensitive to emotional stimuli and its amplitude elevated degree by emotional material is related to subjective valence or intensity of emotional stimuli (Hajcak et al., 2010). Furthermore, LPP might serve as a neural marker of risk for affective psychopathology (Hajcak & Foti, 2020; Moran et al., 2013), such as depression (Speed et al., 2016). For example, greater pre-treatment LPPs to negative stimuli predicted depression treatment outcome (Stange et al., 2017), and blunted LPP to positive images predicted symptoms of depression (Sandre et al., 2019).

Larger LPP amplitudes to negative stimuli have been reported in adult depression (Benau et al., 2019; Dainer-Best et al., 2017), in adolescents with depression (Auerbach et al., 2015; Burkhouse et al., 2017), in young adulthood with depressive symptoms (Xie et al., 2018), as well as in children with maternal history of depression (Speed et al., 2016). These studies suggested that LPP may be a viable biomarker of negative processing biases in depression. However, there are contradictory results. For example, clinical or non-clinical depressed individuals showed blunted LPP responses to unpleasant images (Nikolin et al., 2022), both pleasant and unpleasant images (Hill et al., 2019), and even all emotional faces (Grunewald et al., 2019). Notably, depressed participants exhibited enhanced LPP for self-referential negative words (Auerbach et al., 2015; Dainer-Best et al., 2017) and negative autobiographical memories (Speed et al., 2020), suggesting that the LPP response to self-related or to internal stimuli may be more stable.

Most previous laboratory studies have employed external stimuli such as negative pictures and words to evoke negative emotion (Benau et al., 2019; Nikolin et al., 2022). However, it is possible that imagined or recalled negative scenarios are more closely to the experience of individuals with mood disorders (Bauer & MacNamara, 2021). Several studies have demonstrated the potential to elicit LPP responses to emotional imagery in both healthy and clinical samples (Bauer & MacNamara, 2021; MacNamara, 2018). For instance, healthy individuals exhibited enhanced LPP responses to emotional imagery relative to neutral imagery (MacNamara, 2018), as well as larger LPP responses to positive imagery versus negative imagery (Marmolejo-Ramos et al., 2015; Suess & Rahman, 2015). The clinical findings indicated that depression was associated with reduced LPP response to negative imagery (Bauer & MacNamara, 2021). However, it should be noted that the depressed participants in this clinical study presented complex comorbid symptoms, including generalized anxiety, social anxiety, and posttraumatic stress disorder. Furthermore, the experimental materials only employed general negative imagery rather than idiographic negative imagery. These studies suggested that the heterogeneity of research methods and participant characteristics may potentially affect the obtained results (Bauer & MacNamara, 2021; Benau et al., 2019; Weinberg et al., 2016). Therefore, there is a need for further investigation into the LPP response to emotional imagery in individuals with depression.

Here, we first screened participants who met the diagnostic criteria for depression, and then used pure emotion images (happy, sad, and neutral scene images) as experimental materials. To examine that emotional imagery can also cause the neural response of depressed individuals like external emotional stimuli, this study examined the LPP responses to emotional imagery. Based on cognitive models of depression (Beck, 1967),

we hypothesized that depressed individuals would exhibit an enhanced LPP response to sad imagery than healthy controls. Based on previous studies (Benau et al., 2019; Dainer-Best et al., 2017), we expected that depressed individuals would exhibit an enhanced LPP response to sad imagery relative to happy and neutral imagery, whereas healthy controls would exhibit an enhanced LPP response to happy imagery relative to sad and neutral imagery.

2.Methods

2.1. Participants

Participants were recruited from Jiangxi Normal University through online advertisements. Inclusion criteria for the depressed group were as follows: meeting the diagnostic criteria for current depressive disorder, having a BDI-II score of 14 or higher, and an HDRS-17 score of 8 or higher for depressive symptoms experienced within the past 2 weeks. Participants with bipolar disorder, psychotic disorder, anxiety disorders, or current substance use disorder were excluded. The healthy controls consisted of individuals with no history of neurological or psychiatric illness, a BDI-II score of 13 or lower, and an HDRS-17 score of 7 or lower.

Participants with BDI-II scores above 14 underwent initial screening using Structured Clinical Interview for DSM-5 (SCID; First et al., 2015) during the initial QQ voice interview. Those who met the criteria were invited to the lab for an in-depth clinical interview. All participants were right-handed, had normal or corrected normal vision, provided informed consent prior to the experiment. The Human Research Ethics Committee of Jiangxi Normal University approved the study. EEG data were assessed in 46 depressed participants and 46 healthy controls in the present study. During the encoding-imagery task, 8 participants were excluded due to excessive EEG drift (depression: n=5; control: n=2), or quitting halfway due to discomfort (depression: n=1). Finally, the formal data analysis included 40 depressed participants and 44 healthy controls.

2.2. Measures

First, the current mood disorders were evaluated in all participants with the SCID(First et al., 2015) by two PhDs in clinical psychology supervised by a licensed psychiatrist. Furthermore, the current depression severity and symptomatology were evaluated using the 17-item version of the Hamilton Depression Rating Scale (HDRS-17; Hamilton, 1967) and the Chinese version of the Beck Depression Inventory-Second Edition (BDI-II; Wang et al., 2011). All participants were completed a questionnaire that was contained demographic information and the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973). Demographic characteristics and scale scores of two groups are presented in Table 1. Groups were matched age, education level, and VVIQ score.

Table1. Demographic characteristics and scale scores of depressed individuals and healthy controls

	Depressed individuals (n=40) <i>M</i> ± <i>SD</i>	Depressed individuals (n=40) range	Healthy controls (n=44) <i>M</i> ± <i>SD</i>	Healthy controls (n=44) range	<i>t</i>
Sex(female/male)	25/15	25/15	24/20	24/20	
Age(years)	20.20 ± 1.49	18-25	20.23 ± 1.87	18-25	-0.55
Education level(years)	13.80 ± 0.97	13-16	13.91 ± 1.03	13-16	-0.50
HDRS-17 score	12.80 ± 3.86	8-21	3.36 ± 2.18	0-7	13.96***
BDI-II score	23.43 ± 8.31	14-52	7.39 ± 3.83	0-13	11.53***
VVIQ score	55.37±8.67	41-71	60.43±9.16	43-76	-2.59

*** $p < 0.001$.

2.3. Experimental materials and procedure

This study compiled a new set of materials to ensure that each image contains people and is purely emotional due to images from IAPS with or without people, as well as it specific emotional images affected neural responses of participants (Ferri et al., 2012; Weinberg & Hajcak, 2010). The formal experiment comprised 60 images (20 sad, 20 happy, and 20 neutral). These images of valence ratings indicated that happy images were rated as more pleasant (7.65 ± 0.14 , $p_s < 0.001$) than neutral (5.09 ± 0.26) and sad images (2.46 ± 0.26), and its also higher for neutral image compared to sad images ($p < 0.001$). Additionally, the arousal score was higher for both happy (6.17 ± 0.26) and sad images (6.17 ± 0.26) compared to neutral images (3.05 ± 0.22 , $p_s < 0.001$), but no significant difference was found between the happy and sad images ($p = 0.98$). All images had the same brightness and contrast, measuring 475 x 355 pixels, and were presented on a gray background.

The experimental procedure was adapted from the encoding-retrieval paradigm (Bone et al., 2020), which required participants to first memorize and then recall or imagine (see Figure 1). During encoding, each trial started with a 7-word Chinese title presented for 0.5 seconds, followed by the corresponding image displayed for 4 seconds (with the title remaining above the image). Between trials, a fixation cross was presented for 0.5 seconds. During imagery, each trial began with "Ready" and remained visible until participants pressed the spacebar. This step allowed them to adjust their pace of the task, which is particularly beneficial for depressed participants (Zhou et al., 2021). Upon pressing the spacebar, a crosshair appeared for 0.5 seconds, followed by a title cue displayed for 0.3 seconds. After that, an empty frame with with dimensions matching the image (475 by 355 pixels) appeared for 3.5 seconds. Participants were instructed to vividly imagine the image corresponding to the provided title cue within the given frame. Subsequently, participants rated the subjective vividness and valence of their mental imagery on a 1–9 scale (max. 2 seconds). During the inter-trial intervals, a crosshair was displayed for 2 seconds.

All images randomly divided into 4 blocks, with each block containing 5 sad, happy, and neutral images. Each image was presented three times in a random order during encoding period and visualized three times in pseudo-random order according to title cue during imagery period; each picture was presented or visualized once before any image was repeated. To ensure participants were imagining the corresponding image, participants were required to indicate which of four exemplars they imagined in 7% of the catch trials (Dijkstra et al., 2018). Participants were asked to complete practice experiments before the formal experiment.

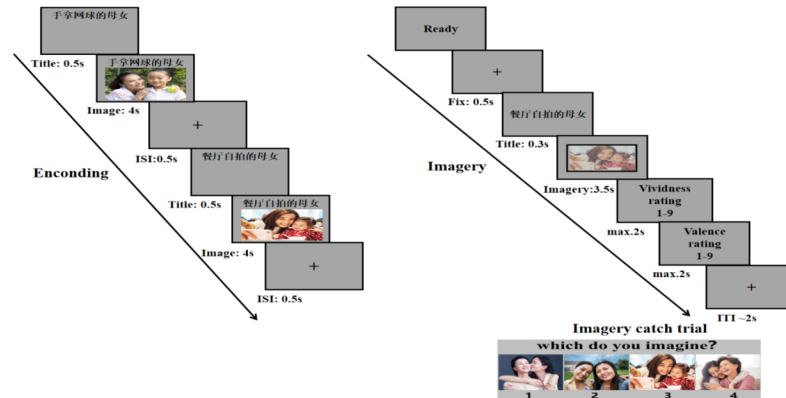


Figure 1. Illustration of alternate encoding-imagery task

Note:餐厅自拍的母女: Mother and daughter taking selfies in a restaurant; 手拿网球的母女: Mother and daughter holding a tennis ball

2.5. EEG recordings and analysis

EEG data were recorded using a 64-channel Neuro-Scan ERP workstation, and the electrode locations were based on the extended international 10/20 system. Vertical EOG and horizontal EOG signals were recorded with electrodes placed above and below each participant's left eye and at the outer canthi of the two eyes, respectively. Electrode impedances were kept below 10k Ω . EEG signals were bandpass filtered between 0.05-100 Hz and digitized with a sample frequency of 1000 Hz.

The data were processed using EEGLab version 2021b. The electrode signals were offline filtered using a 30-Hz low pass filter and a 0.1-Hz high-pass filter. Independent Components Analysis was used to detect and correct ocular artifacts and muscle artifacts. Trials with other artifacts (mean voltage exceeding $\pm 100\mu V$) were also removed. The extracted epochs (from -200 to 2000 ms) were time-locked with the onset of the title cue, and the resulting data were baseline-corrected (-200 to 0 ms). EEG signals were re-referenced offline to average reference.

Based on previous research (Bauer & MacNamara, 2021; Marmolejo-Ramos et al., 2015) and visual inspection of topographic maps (see Figure 4), the LPP was measured by averaging the amplitudes at centroparietal sites (Pz, CPz, Cz, C1 and C2). Furthermore, the LPP was quantified using three distinct time windows: 400–800 ms (early window), 800–1,400 ms (middle window), and 1,400–2,000 ms (late window). EEG data were entered into a 3 (emotion: happy, neutral, sad) \times 3 (time window: early, middle, late) \times 2 (group: depression vs control) mixed model ANOVA. Self-report ratings of imagery valence and vividness were entered into a 3 (emotion: happy, neutral, sad) \times 2 (group: depression vs control) mixed model ANOVA. Greenhouse–Geisser adjustment was employed when the sphericity assumption was violated. Partial eta squared (η^2) values were reported for all analyses, and Bonferroni correction was used for multiple comparisons. Statistical analysis was performed using IBM SPSS Version 26.

3. Results

3.1. Behavioral results

The correct identification rate of the imagined exemplar in the 7% of the catch trials was 94.74% ($\pm 0.07\%$), indicating that all participants performed the task accurately. Furthermore, the score of VVIQ showed a significant positive correlation with averaged vividness ratings ($r = 0.44$, $p < 0.001$), indicating that individuals with higher imagery vividness reported experiencing more vivid imagery during the experiment.

For the scores of imagery valence, there was a main effect of group ($F(1,82) = 5.70$, $p = 0.02$, $\eta^2 = 0.07$), with lower scores for the depressed participants compared to the healthy controls. There was also a main effect of emotion ($F(2,164) = 230.19$, $p < 0.001$, $\eta^2 = 0.74$), with higher scores for happy imagery ($ps < 0.001$) compared to both sad and neutral imagery, as well as for neutral imagery compared to sad imagery ($p < 0.001$). Further, there was a significant interaction of group and emotion ($F(2,164) = 3.11$, $p = 0.047$, $\eta^2 = 0.04$; see Figure 2). Simple effect analysis showed that depressed individuals scored lower in sad ($p = 0.006$) and neutral imagery ($p = 0.03$) compared to the control group. No significant was found in happy imagery between two groups ($p = 0.97$).

For the scores of imagery vividness, there was a main effect of emotion ($F(2,164) = 230.19$, $p < 0.001$, $\eta^2 = 0.74$), with higher scores for happy imagery compared to both sad and neutral imagery ($ps < 0.001$), as well as for neutral imagery compared to sad imagery ($p < 0.001$). No other effects reached significance ($ps > 0.35$).

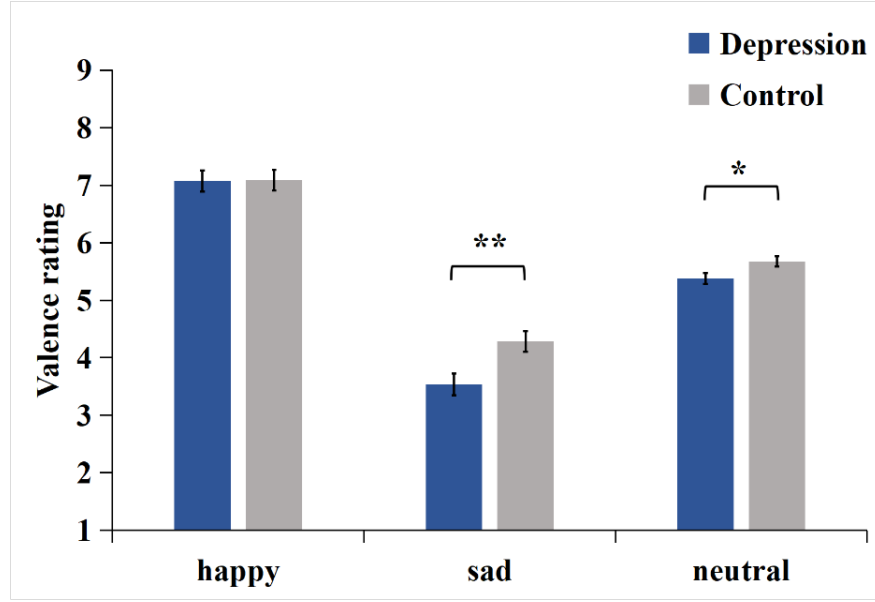


Figure 2. The mean score of imagery valence rating. Error bars represent the standard error. The asterisks indicate significant differences among conditions (** $p < .01$, * $p < .05$).

3.2. ERP results

Repeated-measures ANOVA analysis of LPP amplitudes revealed a significant interaction between group and emotion ($F(2, 164) = 13.40, p < 0.001, \eta_p^2 = 0.14$). Simple effects analyses showed that depressed participants exhibited larger LPP for sad imagery compared to happy imagery ($p = 0.008$); no significant differences were found for sad ($p = 0.05$) and happy imagery ($p = 1.00$) compared to neutral imagery. Conversely, healthy controls exhibited greater LPP for happy imagery than for sad imagery ($p < 0.001$); no significant differences were found for happy ($p = 0.08$) and sad imagery ($p = 0.17$) compared to neutral imagery. Additionally, depressed individuals exhibited significantly larger LPP for sad imagery compared to healthy controls ($p = 0.03$). The main effect of the time window was significant ($F(2, 164) = 14.05, p < 0.001, \eta_p^2 = 0.15$), and wherein the LPP amplitudes were more positive in the early ($p = 0.003$) and middle ($p < 0.001$) time windows compared to the late time window. The main effects of group and emotion, as well as the interaction effects of group and time window, emotion and time window, were not significant ($ps > 0.23$).

The interaction effect of group \times emotion \times time window was significant ($F(4, 328) = 14.05, p = 0.03, \eta_p^2 = 0.03$), followed up by separate analyses of the three time windows.

Early LPP amplitudes. The results showed a significant interaction effect between group and emotion ($F(2, 164) = 11.07, p < 0.001, \eta_p^2 = 0.12$). Simple effect analysis showed that depressed participants exhibited significantly larger early LPP for sad imagery compared to both happy ($p = 0.03$) and neutral imagery ($p = 0.02$). Conversely, healthy controls exhibited greater early LPP for happy imagery than for sad imagery ($p = 0.001$), and greater but non-significant than neutral imagery ($p = 0.18$). No other effects reached significance ($ps > 0.39$).

Middle LPP amplitudes. The results revealed a significant interaction effect between group and emotion ($F(2, 164) = 12.40, p < 0.001, \eta_p^2 = 0.13$). Simple effect analysis showed that depressed participants exhibited significantly larger middle LPP for sad imagery compared to both happy ($p = 0.003$) and neutral imagery ($p = 0.02$). Conversely, healthy controls exhibited greater middle LPP for happy imagery compared to sad imagery ($p = 0.003$), and greater but non-significant than neutral imagery ($p = 0.07$). Additionally, depressed

individuals exhibited larger middle LPP for sad imagery relative to healthy controls ($p = 0.02$). No other effects reached significance ($ps > 0.29$).

Late LPP amplitudes. The results revealed a significant interaction effect between group and emotion ($F(2, 164) = 10.73, p < 0.001, \eta_p^2 = 0.12$). Simple effect analysis showed that depressed participants exhibited significantly larger late LPP for sad imagery compared to happy imagery ($p = 0.04$), but no significant difference was observed between late LPP for happy imagery and neutral imagery ($p = 0.56$). For the control group, happy imagery elicited greater late LPP than sad imagery ($p = 0.001$), and greater but non-significant than neutral imagery ($p = 0.17$). Furthermore, the depression group exhibited significantly larger late LPP for sad imagery compared to the control group ($p = 0.02$). No other effects reached significance ($ps > 0.45$). See Figure 3 and Figure 4.

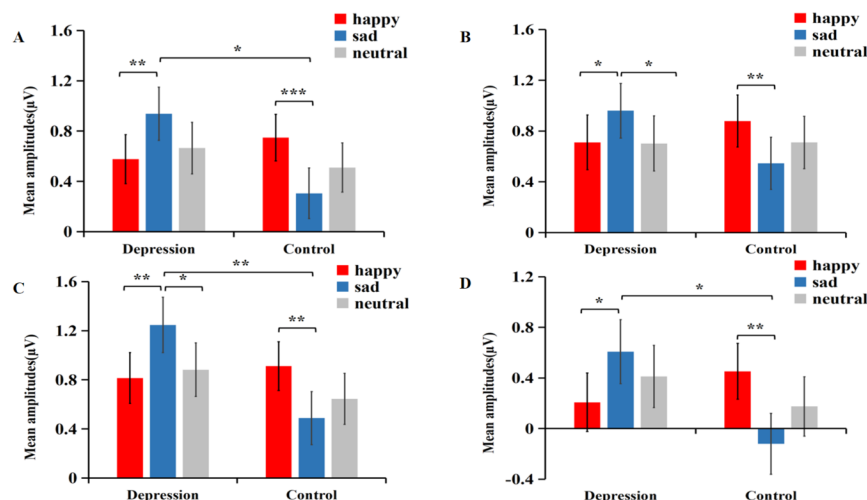


Figure 3. LPP. (A): Mean LPP amplitudes across emotion, conditions, and time windows. (B): Mean early LPP amplitudes. (C): Mean middle LPP amplitudes. (D): Mean late LPP amplitudes. Error bars represent the standard error. The asterisks indicate significant differences among conditions (* $p < .05$, ** $p < .01$, *** $p < .001$).

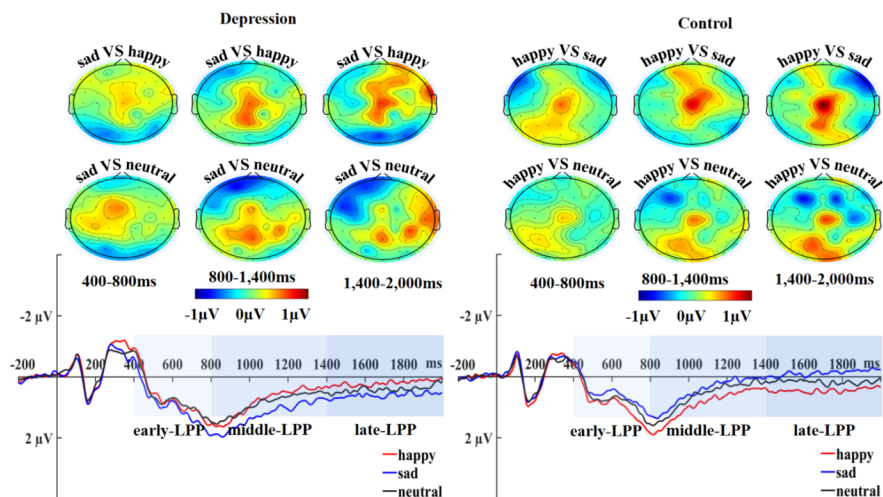


Figure 4. Upper panels: Scalp distributions of the differences for depressed individuals (left) and for healthy

controls (right) are depicted. Lower panels: Grand-average ERP waveforms were pooled across electrode sites Pz, Cz, CPz, C1, and C2 during imagery for depression (left) and control (right).

4. Discussion

In this study, we investigated the neural response to emotional imagery in depressed individuals and healthy controls when they imagine different emotional images using an encoding-imagery paradigm. The behavioral results showed that depressed individuals scored lower on valence ratings for sad and neutral imagery compared to healthy controls. Furthermore, the ERP findings revealed that depressed participants exhibited enhanced LPP responses to sad imagery relative to happy imagery, whereas healthy controls showed greater LPP response to happy imagery relative to sad imagery. Notably, depressed individuals exhibited enhanced LPP responses to sad imagery compared to healthy controls in both middle and late time windows, but not during the early time window.

Our findings indicate that there are differential LPP responses to emotional imagery over centroparietal sites between depressed individuals and healthy controls, which are broadly consistent with previously observed LPP responses in depression (Auerbach et al., 2015; Dainer-Best et al., 2017; Speed et al., 2020). Specifically, depressed individuals exhibited enhanced LPP responses to sad imagery relative to happy imagery, whereas healthy controls demonstrated the opposite pattern. Namely, depressed individuals exhibit similar pattern of neural responses to sad imagery as they do to negative autobiographical memories, and self-referenced negative words. These findings may be related to the sustained attentional engagement to negative stimuli in depressed individuals (Auerbach et al., 2015; Dainer-Best et al., 2017), and may be partially explained by the potent emotional impact of imagery and its close association with emotional memory (Holmes et al., 2009, 2016). Notably, no significant difference was found in LPP responses between emotional (happy and sad) and neutral imagery, which probably because the LPP response to neutral images containing people were comparable to emotional images (Ferri et al., 2012; Weinberg & Hajcak, 2010).

Critically, depressed participants showed larger LPP responses to sad imagery compared to healthy controls, especially during the middle and late time windows. These findings support the presence of mood-congruent imagery biases in depressed individuals (LeMoult & Gotlib, 2019). According to Beck's cognitive model of depression, individuals with depression have mood-congruent schemas that lead depressed individuals to exhibit negative information-processing biases and distort the processing of emotional stimuli, leading to enhanced reactivity (Beck, 1967). Additionally, the negative bias for sad imagery in depressed individuals was mainly observed during the middle and late time windows, suggesting that depression-related abnormalities in emotional processing primarily occur more during the top-down attentional capture phase rather than automatic attentional capture phase of emotional information. Namely, depression risk is associated with later and more elaborate processing of negative emotional information (Speed et al., 2016). Benau et al. (2019) also reported group differences in LPP were specific to the middle time window. The possible reason is that the earlier LPP reflects automatic attentional capture of salient information, and the later LPP is more influenced by top-down attentional capture (Hajcak et al., 2010; Olofsson et al., 2008). In summary, our findings indicate that sad imagery captures more cognitive resources during later stages of information processing in depressed individuals.

However, our results contrary to the study conducted by Bauer and MacNamara (2021), where they observed a blunted LPP to negative imagery in depressed individuals. These discrepancies in the LPP to valence may be attributed to variations in factors such as age of depression onset, participant characteristics, stimulus properties, and task types (Benau et al., 2019; Grunewald et al., 2019; Weinberg et al., 2016). Bauer and MacNamara's (2021) study involved participants with complex internalizing psychopathology and utilized general negative imagery as stimuli, which may have influenced the neural response. Depressed individuals process negative stimuli, particularly sad ones, better and more accurately (Delle-Vigne et al., 2014). In our study, we utilized sad and happy images that contain people as emotional stimuli instead of general positive (i.e., erotic, food or flower images) and negative stimuli (i.e., sad or threatening scenes). Consequently, we did not observe a main effect between depressed individuals and healthy controls in LPP amplitudes for

happy and neutral imagery, but only for sad imagery. The differences likely reflect specific processing biases toward sad imagery rather than a broad bias in emotional information processing. Collectively, our findings suggest that an enhanced LPP response to sad imagery may serve as a potential biomarker of depression risk.

In line with the ERP results, depressed individuals rated sad and neutral imagery more negatively compared to healthy controls, while their ratings for happy imagery were comparable. Our behavioral results are consistent with previous studies showing a bias toward endorsing and recall more negative stimuli in depression (Benau et al., 2019; Dainer-Best et al., 2017; Speed et al., 2016). The finding provides behavioral evidence for depressed participants experiencing more negative imagery (Holmes et al., 2016; Weßlau & Steil, 2014), supporting the presence of mood-congruent biases in depression. Overall, the tendency toward a negativity bias in imagery valence ratings observed in depressed individuals may serve as a potential cognitive feature associated with vulnerability to depression.

Caution should be exercised when interpreting the present results due to several limitations. Firstly, the relatively small sample size limited the interpretability of effect sizes, and the use of homogeneous college student limited the generalizability of these findings. Future studies should employ larger and more diverse populations to enhance statistical power and generalize to broader populations. Second, our study compiled a new set of pure emotion materials to ensure idiographic emotional stimuli for happy, sad, and neutral images. However, these images were used for the first time in the present study, replication in future studies is necessary to establish their reliability and validity. Finally, although our study identified enhanced LPP activity to sad imagery as a potential risk indicator for depression, it did not include longitudinal follow-up to determine whether those participants with enhanced LPP to sad imagery subsequently develop more severe depressive symptoms.

In summary, this study contributes novel behavioral and electrophysiological evidence regarding emotional imagery differences between depressed individuals and healthy controls. Both behavioral and ERP results support the presence of a mood-congruent processing bias in depressed individuals. Additionally, sad imagery bias is evident in the middle and late time windows, indicating a greater engagement of top-down attentional resources in depressed individuals. These findings shed light on the cognitive and neural processes underlying emotional imagery in depression.

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