Does Pathological Internet Use Change Emotion Processing? An Event-Related Potential Study

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ABSTRACT

The current study aimed to examine how pathological internet users (PIUs) process emotional stimuli on the internet and in real contexts. Twenty-one PIUs and 25 normal controls (NCs) were recruited based on their score on the Adolescent Pathological Internet Use Scale. They were asked to judge the valence of emotional words in a subliminal priming task. The results showed that participants responded more slowly to and had smaller P1 amplitudes for negative emotional words than for positive emotional words. Moreover, the late positive potential (LPP) amplitude for PIUs was smaller than that for NCs. Results showed a larger LPP of negative words in the internet-related priming context for NCs and the internet-unrelated priming context for PIUs. These findings indicate that pathological internet use affects emotional stimuli processing, especially in the late stage of cognitive processing.

KEYWORDS

pathological internet use
emotion processing
negative bias
internet-related words

INTRODUCTION

World Internet Usage and Population Statistics reported that more than 5.3 billion people around the world used the internet by January 2022 (Internet World Stats, 2022). According to the China Internet Network Information Center (CNNIC, 2022), the number of netizens in China reached a total of 1032 million with an internet penetration rate of 73.0%. The internet not only shapes behavioral patterns, but also changes people's cognitive functioning (e.g., Dieter et al., 2017; Zhao et al., 2018). With the popularity and widespread promotion of the internet, excessive use has become a vital topic in public health. Generally, pathological internet use refers to irrational and uncontrolled internet use, and health practitioners have identified it as a problematic behavior (Lei & Yang, 2007; Young, 1998). Prior research has revealed that pathological internet users (PIUs) perform worse in tasks related to the cognitive processes, such as memory (Zhao et al., 2018) and attention (Peng et al., 2018). However, limited research has examined whether pathological internet use weakens emotional processing (e.g., Wu & Zheng, 2012; Zheng, 2008). Thus, clarifying the effect of pathological internet use on emotional processing not only helps uncover its media effect, but also provides vital evidence for treatment.

Previous studies have suggested that internet addiction is associated with emotional competence deficits, such as a lack of acceptance of emotional responses, limited access to emotion regulation strategies, and reduced impulse control (Dieter et al., 2017; Hormes et al., 2014). Pathological internet users (PIUs) may experience more negative emotions (e.g., loneliness and depression) and fewer positive ones (e.g., happiness and life satisfaction; Longstreet et al., 2018). The mood-congruent hypothesis argues that people pay attention to stimuli consistent with their mood (Becker & Leinenger, 2011). Furthermore, scholars have provided evidence to support the claim that PIUs may develop a processing bias toward negative emotions (Lei et al., 2017; Wu & Zheng, 2012). For instance, Wu and Zheng (2012) adapted the Space-Stroop task and demonstrated that adolescent PIUs responded significantly more slowly to negative emotional words than controls. However, they found no significant differences between the two groups of adolescents in processing positive emotional and neutral words. In addition, Lei et al. (2017) used the visual search paradigm to investigate attentional biases to realistic and cartoon expressive faces for people suffering from internet addiction and controls. Results showed that the former had faster orientation to threatening stimuli and exhibited difficulty disengaging from such stimuli, thus suggesting pathological internet use can change individual attention patterns.

Furthermore, in recent years, a growing body of studies used the event-related potential (ERP) technology to investigate emotional bias (Bistricky et al., 2014; Cui et al., 2021; Morel et al., 2014). Compared to behavioral measurements, ERP technology can capture more accurate and objective information about the temporal dynamics of attentional processes (Eimer & Holmes, 2007). The high temporal resolution of ERP allows us to distinguish between early and late processing stages and gain a better understanding of the study question. Recently, using ERP technology, Hou et al. (2019) found that people suffering from internet addiction produced a significantly higher amplitude of P1 on

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viewing lonely images compared with happy images, indicating that they distributed more attention resources to loneliness-related information.

However, prior studies have only revealed the association between pathological internet use and processing biases toward negative emotions in the real world. Whether this association also exists in the virtual context remains to be further studied. PIUs have much exposure to the internet in their daily lives. Therefore, exploring how they process emotion-triggering information in the internet environment is necessary. According to the explanation of the compensatory internet use model, the reason why PIUs spend a lot of time online despite experiencing negative outcomes is that pathological internet use is the result of people using the internet to escape real-life issues or alleviate dysphoric moods (Kardefelt-Winther, 2014). For example, individuals who lack social relationships might react with a motivation to use a social networking site to obtain feelings of social connectedness and belongingness (Kardefelt-Winther, 2014; Kuss & Griffiths, 2011). Considering the mood modification effect of behavioral addictions (Griffiths, 2005), although pathological internet use can deteriorate mood in the long term, PIUs may experience temporary happiness during being online. Zhu et al. (2021) found that online activities could improve the mood of PIUs effectively. They obtained greater pleasure from online comments compared with normal controls (NCs). This result was explained by the flow experience theory (Zhu et al, 2021), which stated that PIUs would form a fixed experience pattern such as the feelings of concentration and enjoyment while immersing themselves in the internet (Ghani & Desphande, 1994). From this perspective, the internet-related stimulus itself can evoke positive emotions in them (Zhu et al., 2021). Furthermore, the mood-congruent effect on emotion processing may decrease, thus resulting in the disappearance of negative bias for PIUs while online.

To date, no research has investigated how PIUs process emotion in the virtual context. This study attempted to address this gap by examining the emotion processing of PIUs and NCs after priming the virtual or real environments. To exclude the interference of subjective consciousness, we employed a subliminal priming task in the current study, which has been used widely to investigate the impact of subliminal priming stimuli on cognitive processes (Eimer & Schlaghecken, 2003; Leins et al., 2021). Moreover, ERP was adopted in the present study. In ERP studies of emotional bias, the P1 and the late positive potential (LPP) components have been frequently the focus (Cui et al., 2021; Hou et al., 2019; Scott et al., 2009). The P1 is an early ERP component related to the automatic allocation of attentional resources (Bistricky et al., 2014; Scott et al., 2009). A study by Hou et al. (2019) showed that people suffering from internet addiction exhibited an increased P1 amplitude in response to lonely scenes relative to happy scenes. The LPP is a component reflecting sustained emotional processing, which is associated with affective labeling, stimulus evaluation, and motivated attentional processes (Cui et al., 2021; Krompinger et al., 2008). Thus, in the current study, we compared the differences in the P1 and LPP components between PIUs and NCs.

In sum, the current study aimed to investigate whether PIUs and NCs process emotional stimuli differently in the virtual context and the real context. On the basis of the above arguments, the following hypotheses were put forward: (a) PIUs would exhibit a more negative bias than NCs in the real context; (b) PIUs would exhibit a more positive bias than NCs in the internet context.

METHOD

Participants

A total of 500 college students were recruited for the survey on pathological internet use in the authors' affiliated institution. Based on previous studies (Lei & Yang, 2007; Zhao et al., 2018), we categorized the participants who scored 120 or higher on the Adolescent Pathological Internet Use Scale (APIUS) as PIUs and grouped those who scored less than 114 as NCs. In the sample, about 10% of participants were PIUs. We randomly invited participants from both groups to take part in the experiment. In total, 21 PIUs and 25 NCs responded to our invitation and enrolled in the experiment. In the data analysis, four participants were excluded, two of which had their behavioral response time exceed three SDs. The other two participants were removed because their ERP waveform was seriously distorted. Finally, 42 participants were analyzed, including 20 PIUs (M = 121.85, SD = 11.29) and 22 NCs (M = 80.00, SD = 18.63). Participants were between 18 and 26 years old (M = 20.83, SD = 2.16). Sixteen were male, and 26 were female. There were no statistically significant differences between PIUs and NCs in age (M = 20.65, SD = 2.46; M = 21.00, SD = 1.90, t = -0.52, p = .61) or gender (7 males and 13 females; 9 males and 13 females, t = 0.39, p = .70). All participants were healthy and right-handed, with normal or corrected-to-normal vision. Participants self-reported that they had no history of brain injuries or affective disorders. They completed written consent forms and received 30 yuan after the experiment as compensation for their time. The study was approved by the authors' affiliated Human Ethics Committee for Brain Mapping Research.

Materials

ADOLESCENT PATHOLOGICAL INTERNET USE SCALE (APIUS)

The APIUS is a 38-item self-report scale designed to identify PIUs (Lei & Yang, 2007). It consists of the following six dimensions: salience (e.g., "Once I go online, I forget nearly everything else"), mood alteration (e.g., "When I have some trouble, surfing the internet makes me feel better"), tolerance (e.g., "To continue to surf the internet, I would instead not go to the bathroom"), compulsive internet use/withdrawal symptoms (e.g., "When I cannot go online, I am dying to know what is happening online"), social comfort (e.g., "Communicating with others online makes me feel secure"), and adverse outcomes (e.g., "Surfing the internet harms my health"). Participants rate each item on a five-point Likert scale (1 = *never true*; 5 = *always true*), with higher scores indicating higher levels of pathological internet use. The APIUS has been widely used to identify PIUs among Chinese college students (Zhao et al., 2018). The Cronbach's α reliability coefficient was .96 in this study.

PRIMING WORDS AND TARGET WORDS

We randomly selected 60 internet words (e.g., "WeChat" and "website") and 60 non-internet words (e.g., "school" and "canteen") as the priming words from the self-made Internet Words System, which consisted of 257 internet-related words and 156 internet-unrelated words. The internet-related and internet-unrelated words were similar in terms of familiarity and pleasantness (*ps* > .05) but differed in internet relevancy ($p < .05$). The target words included 60 positive emotion words (e.g., "joyful") and 60 negative emotion words (e.g., "sad"), which were adopted from Kong et al. (2012). All the words were in Chinese.

Procedure

We used a 2 × 2 × 2 (participant type [PIUs, NCs] × 2 priming words [internet-related, internet-unrelated] × target words [positive emotional, negative emotional]) mixed design. The between-subjects factor was the participant type, the within-subject factors were the priming words and target words, and the dependent variables were the response time (RT) and the amplitudes of P1 and LPP. We asked the participants to sit in a quiet room, with a distance of approximately 60 cm away from the computer screen and a vertical visual angle of less than 10°. The refresh rate of the computer was 100 Hz. We instructed them to pay attention to the center of the computer screen, avoid moving their bodies, and minimize blinking.

We presented the stimuli in E-prime 2.0. Before the experimental session, all participants read the instructions carefully and performed a practice session of 12 trials. The experimental session comprised two blocks, with 60 internet-related words and 60 internet-unrelated words in each block. The trials in a block were presented randomly, and the two blocks had two-minute breaks in between. For each trial (see Figure 1), the fixation cross was presented for 500 ms in the center of the screen. Subsequently, the priming word appeared for 14 ms, followed by a backward mask for 40 ms and a blank screen for 46 ms. Finally, the target stimuli were displayed for 1000 ms, with a 1500-ms blank screen with a question mark. If the participants perceived the emotional words as positive, they responded by pressing "1"; otherwise (or perceived the word as negative), they responded by pressing "2". The duration of the entire experiment was approximately 20 minutes.

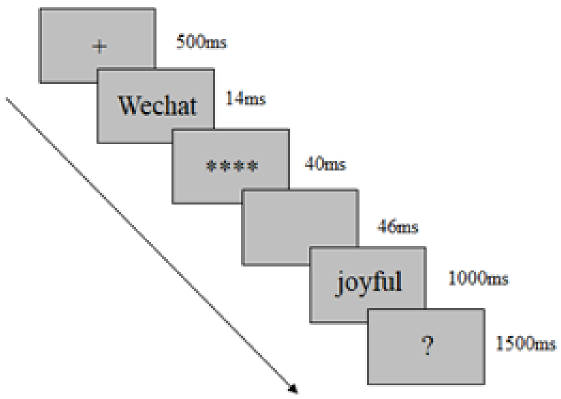

FIGURE 1.
The procedure for each trial in the current study.

Event-Related Potential Recordings and Analysis

Electroencephalograms (EEGs) were continuously recorded by 64 scalp silver/silver-chloride electrodes while the participants completed the experiment. The recording sampling rate was 500 Hz and the amplifier band-pass was 0.05–100 Hz for each channel. Electrode impedance was kept below 5 kΩ. Electrodes were referenced to an electrode at the left mastoid and rereferenced offline to the average of bilateral mastoid references (Luck, 2014). The horizontal electrocardiogram (EOG) and vertical EOG were recorded from electrodes on the outer canthi of both eyes and below and above the left eye, respectively.

The ERP data were analyzed using the Brain Products analysis system. Offline EEG data were rereferenced to the mean value of the left and right mastoids and filtered with a band-pass of 0.01–30 Hz. Independent component analysis (ICA) was used to remove ocular artifacts. In addition, filtered data were segmented, ranging from 200 ms prior to the stimuli to 800 ms after onset. The 200 ms segment before the onset of priming stimuli served as the baseline. According to previous literature (Krompinger et al., 2008; Schomberg et al., 2016; Scott et al., 2009) and grand average waves, the P1 component (80–160 ms) and LPP component (350–600 ms) were analyzed. Three electrodes (PO7, OZ, and PO8) were included for P1, while five electrodes (Fz, FCz, Cz, CPz, and Pz) were included for LPP. Statistical analysis was conducted using IBM SPSS 25.0.

RESULTS

Behavioral Data

Taking the RT as the dependent variable and participant type, priming words and target words as independent variables, we conducted a 2 × 2 × 2 (participant type [PIUs, NCs] × priming words [internet-related, internet-unrelated] × target words [positive emotional, negative emotional]) analysis of variance (ANOVA, see Table 1). Results showed that the main effect of the target words was statistically significant, $F(1, 40) = 34.19$, $p < .001$, $\eta_p^2 = 0.46$. Further analysis revealed that the participants responded to positive emotional words (583.12 ± 13.10 ms) faster than to negative emotional words (613.74 ± 14.61 ms). Other main effects and interactions were not significant.

Event-Related Potential Data

Four-way repeated-measures ANOVAs were conducted on the P1 amplitudes. The factors were participant type (PIUs or NCs), priming words (internet-related or internet-unrelated), target words (positive emotional or negative emotional), and electrodes. Results showed a statistically significant main effect of target words, $F(1, 40) = 7.86$, $p = .008$, $\eta_p^2 = 0.16$. Further analysis showed that the P1 amplitude of positive emotional words (−0.55 ± 0.46 μV) was statistically significantly larger than that of negative emotional words (−0.32 ± 0.47 μV). Other main effects and interactions were not statistically significant.

TABLE 1.
The Analysis of Variance Results for the Response Times

Effect	*df*	*F*	*p*	η_p^2
Participant type	1	2.40	.13	0.06
Priming words	1	0.13	.72	0.00
Target words	1	34.19	< .001***	0.46
Subject type × priming words	1	0.05	.82	0.00
Subject type × target words	1	1.37	.25	0.03
Priming words × target words	1	*1.84*	.18	0.04
Subject type × priming words* target words	1	0.06	.81	0.00

Moreover, the same analysis was conducted on the amplitudes of LPP. Results showed a statistically significant main effect of participant type, $F(1, 40) = 5.66$, $p = .02$, $\eta_p^2 = 0.12$. Further analysis showed that the amplitude of PIUs (2.78 ± 0.49 μV) was significantly lower than that of NCs (4.40 ± 0.47 μV). The results also revealed a marginally statistically significant main effect of the target word, $F(1, 40) = 3.87$, $p = .056$, $\eta_p^2 = 0.09$. The amplitudes of negative emotional words (3.72 ± 0.36 μV) were marginally statistically significantly higher than that of positive emotional words (3.46 ± 0.33 μV). Additionally, the interaction effect between priming type, target type, and participant type was statistically significant, $F(1, 40) = 7.32$, $p = .01$, $\eta_p^2 = 0.16$. The simple effect analysis showed that for NCs, the mean amplitudes of negative and positive emotional words were significantly different in the internet-related priming condition, $F(1, 21) = 6.97$, $p = .015$, $\eta_p^2 = 0.25$. The mean amplitudes of positive emotional words (4.24 ± 0.38 μV) were statistically significantly lower than those of negative emotional words (4.77 ± 0.48 μV), whereas no such differences were observed in the internet-unrelated priming condition (see Figure 2). For PIUs, when the priming words were internet-unrelated, the mean amplitudes of positive emotional words (2.59 ± 0.55 μV) were statistically significantly lower than those of negative emotional words (3.09 ± 0.60 μV), $F(1, 19) = 4.57$, $p = .046$, $\eta_p^2 = 0.19$. However, PIUs exhibited no statistically significant differences in the internet-related priming condition (see Figure 3). The average LPP amplitude and topography of the PIUs and NCs groups are shown in Figures 4 and 5.

DISCUSSION

The present study first investigated the emotion processing of PIUs on the internet and in real life contexts. First, consistent with our hypothesis, larger LPP amplitudes for negative words were found in the internet-related condition for NCs and in the internet-unrelated condition for PIUs. The LPP is an indicator reflecting directed and motivated attention and emotion evaluation processes (Cui et al., 2021; Krompinger et al., 2008). According to existing studies, the attentional load has an important impact on emotional processing (Hsu & Pessoa, 2007). Individuals tend to give priority to negative stimuli when attentional resources are constrained, whereas positive stimuli can be equally attended and processed when the resources are sufficient (Huang & Luo, 2009). Emotional information is more abundant and intensive in the internet environment than that in the real world (Goldenberg & Gross, 2020). The NCs may process preferentially negative stimuli while facing plenty of stimulation, which leads to a negative bias in the internet background. However, PIUs may suffer from more negative emotional symptoms, such as depression and loneliness, in real life (Longstreet et al., 2018). Hence, they tend to invest more resources in negative words consistent with their emotional state than in positive words (Lei et al., 2017; Wu & Zheng, 2012). When PIUs access the internet, they can obtain positive experiences. As a result, they may associate online information with a positive emotional state. The mood-enhancing effect of the internet is probably why the negative processing bias does not exist for PIUs on the internet. Furthermore, research

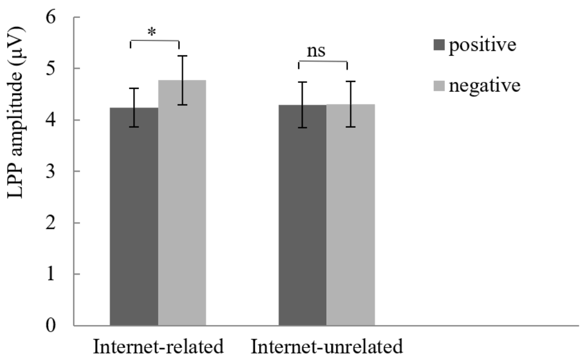

FIGURE 2.
The late positive potential (LPP) amplitude of the normal control group.

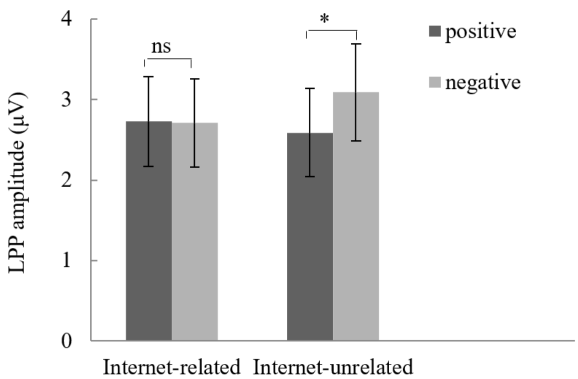

FIGURE 3.
The late positive potential (LPP) amplitude of the pathological internet user group.

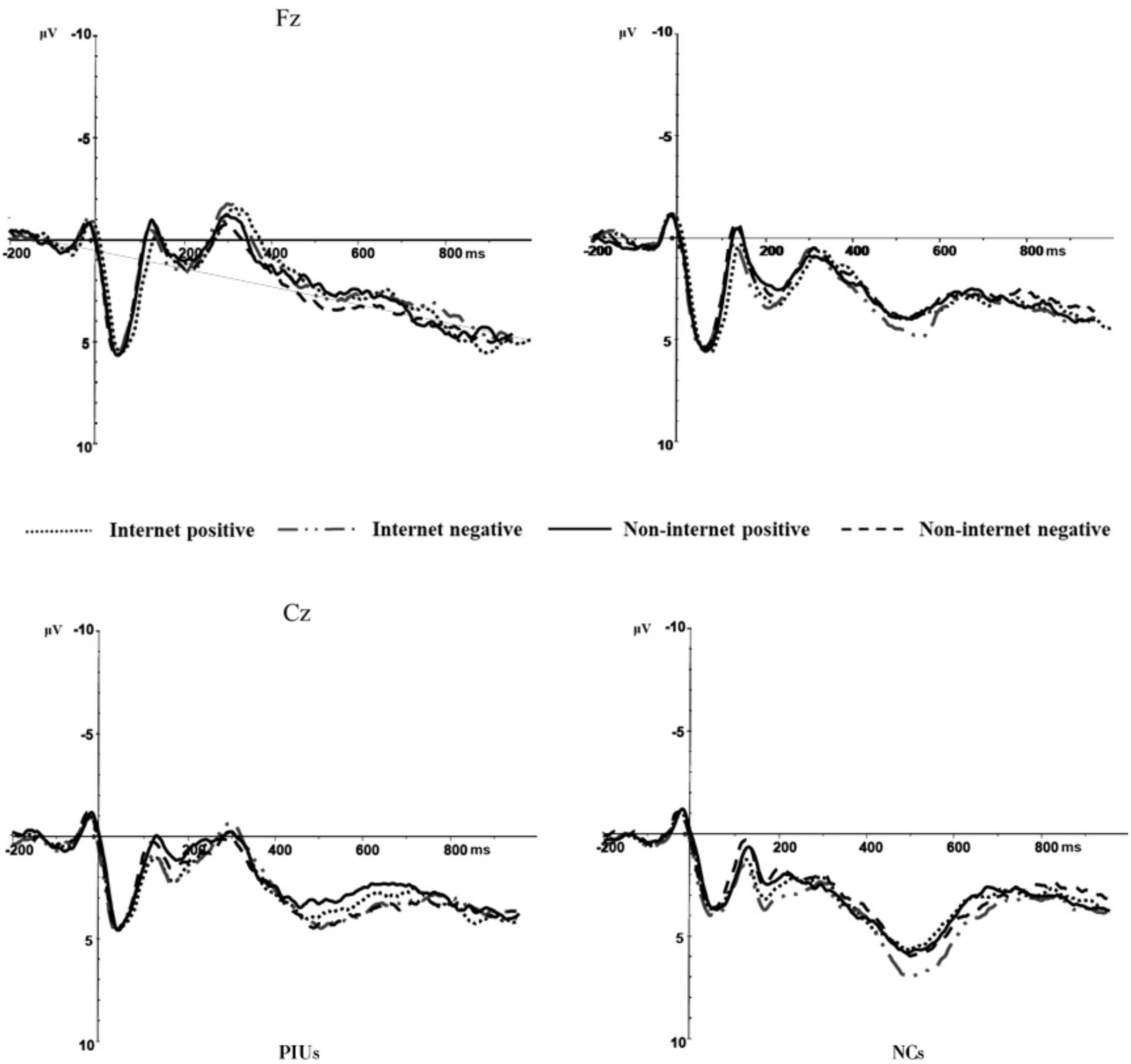

FIGURE 4.

The average late positive potential (LPP) amplitude of the pathological internet user (PIU) and normal control (NC) groups.

has suggested that negative bias is characterized as a priority of negative stimuli in allocating attentional resources, leading individuals to excessive exposure to unpleasant information and increasing their risk of psychological problems (Hou et al., 2021). For PIUs, the negative bias in the real world may aggravate negative moods, resulting in them spending more time on the internet as an emotion regulation strategy. Alternatively, for NCs, negative bias on the internet would activate the aversive motivational system that promotes defensive behavior (Yuan et al., 2019), preventing them from immersing in the internet for a long time. Additionally, the LPP results also imply that the emotional negativity bias may occur in the late stages of emotion processing. Although the LPP results are consistent with previous behaviour studies showing a negative bias for PIUs relative to NCs in the real life context (Lei et al., 2017; Wu & Zheng, 2012), our behavioral results showed no difference in emotion processing between PIUs and NCs. We surmise that the behavioral indicator was not sensitive enough to distinguish such differences after adding a context variable (internet/ real world).

Second, we also found that the LPP amplitudes were significantly smaller for PIUs than for NCs. This outcome indicates that PIUs may have difficulties in perceiving and evaluating emotional stimuli, which is probably because PIUs are immersed in the internet for extended periods, thus leading to a lack of offline social interactions and emotional communication (Kraut et al., 1998). As reported by Dieter et al. (2017), internet addiction is negatively related to emotional competence (e.g., recognizing, controlling, and expressing emotions). Notably, the positive emotional words induced a larger P1 amplitude than the negative emotional words, which was inconsistent with previous studies (Huang & Luo, 2009; Smith et al., 2003). This outcome suggests that more attention resources are allocated to the positive stimuli than the negative

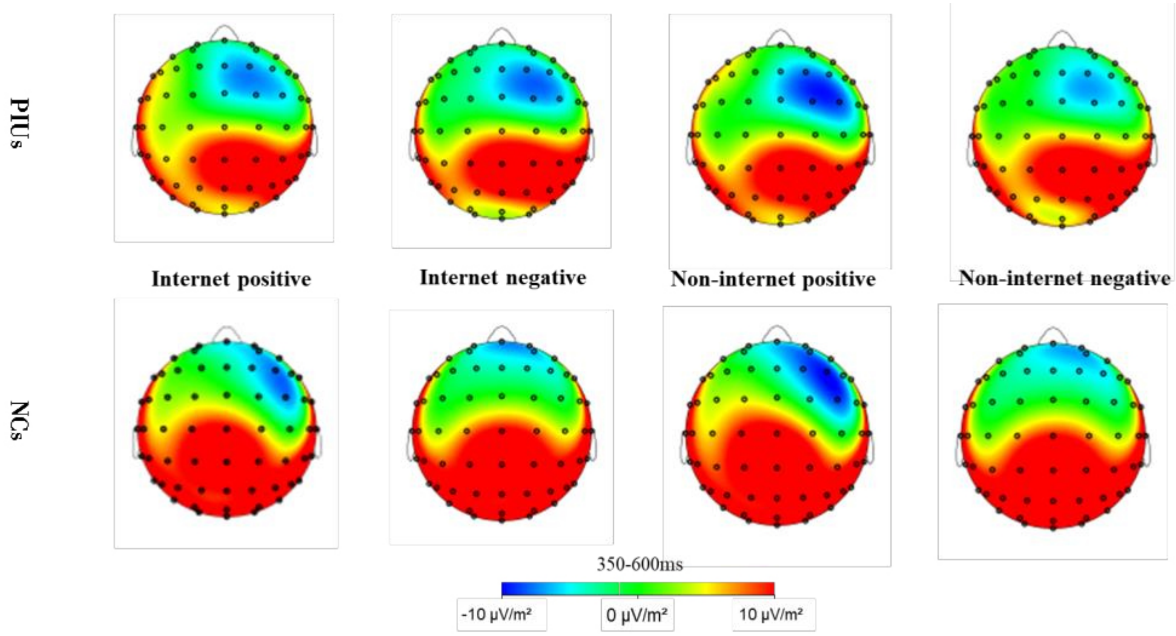

FIGURE 5.
Topography of the late positive potential (LPP) for the pathological internet user (PIU) and normal control (NC) groups.

stimuli in the early processing period. Although this finding is interesting, the underlying explanations need to be investigated further.

This study confirms the influence of pathological internet use on emotion processing in the implicit priming task using behavioral and neuroimaging methods. The findings expand the previous research on pathological internet use and emotional processes, enrich the theory of internet use, and offer a deeper insight into the development and maintenance of pathological internet use. In practice, our study suggests that emotional bias can be used to recognize and treat internet addiction. The negative bias in the real world for PIUs weakens their perception of positive information and reinforces their motivation to go online to compensate for negative feelings. Therefore, changing the emotional bias of PIUs may be a promising way of reducing their frequency of internet use. However, this study still has the following limitations. First, participants were selected from a normal university in China. There are more female than male students in such universities. Therefore, the gender distribution in our sample was slightly skewed. While we controlled for the gender difference between PIUs and NCs, the generalization of the findings needs to be validated by future work in a gender-balanced sample. Second, Hou et al. (2019) found that internet addicts had a bias toward lonely stimuli from P1 components. However, our study did not reveal differences between PIUs and NCs in P1, which may imply that it is necessary to explore the processing of different types of negative emotions (e.g., loneliness, fear, and sadness) among PIUs in the future. Third, we indicated that PIUs and NCs process emotional stimuli differently. However, the underlying mechanism remains unclear. Future studies can examine the brain imaging of emotional processing between PIUs and NCs. Finally, PIUs have defects in emotional regulation (Dieter et al., 2017), and individuals with dysfunctional emotional regulation (such as depression) are more likely to be addicted to the internet (Liang et al., 2016). This study only considers the side of excessive internet use on emotional processing. However, the other side of emotional regulation on internet use is also important. Therefore, researchers must investigate the relationship between internet use and emotional process from the dynamic interaction perspective in future research.

CONCLUSION

PIUs have a negative emotional bias in the real world and NCs have a similar bias in the virtual world. Both of these biases occur in the late evaluation stage of emotion processing. In addition, excessive internet use impairs the emotional evaluation of PIUs.

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DATA AVAILABILITY

The datasets generated and analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request

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