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Emotional processing deficits in individuals with problematic pornography use: Unpleasant bias and pleasant blunting

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FULL-LENGTH REPORT

ABSTRACT

Background and aims: A growing body of evidence indicates a connection between emotional processes and the emergence and progression of addiction. However, scant research has examined the involvement of emotional processing within the framework of problematic pornography use (PPU). This study aimed to examine the electrophysiological and subjective differences in emotional processing between male individuals with PPU and healthy controls (HCs) following exposure to everyday affective images. *Methods:* Event-related potentials (ERPs) were recorded from 42 PPU participants (mean age = 20.14 years, *SD* = 1.35) and 45 HCs (mean age = 20.04 years, *SD* = 1.45) during an oddball task, in which unpleasant, pleasant, and neutral images were presented as deviant stimuli, while a neutral kettle image served as the standard stimulus. The Self-Assessment Manikin (SAM) was employed to assess participants' subjective experience on the dimensions of valence and arousal. *Results:* Regarding subjective measures of emotion, individuals with PPU reported lower valence ratings for unpleasant images compared to HCs. In terms of electrophysiological measures of emotion, PPU participants reported larger P2 amplitudes for unpleasant pictures compared to both pleasant and neutral pictures. Moreover, HCs showed enhanced P3 amplitudes in response to pleasant images compared to neutral images, whereas this effect was not observed in PPU participants. *Discussion and Conclusion:* These findings indicate that individuals with PPU may display deficits in emotional processing characterized by enhanced responsiveness to negative stimuli and attenuated responsiveness to positive stimuli. The heightened sensitivity to negative stimuli may contribute to the inclination of individuals with PPU to engage in pornography as a coping mechanism for stress regulation. Conversely, their diminished sensitivity to positive stimuli presents a challenge in seeking alternative natural rewards to counter potentially addictive behaviors.

KEYWORDS

problematic pornography use, emotional processing, compulsive sexual behavior, event-related potentials

INTRODUCTION

The widespread availability of internet pornography has led to a notable rise in the number of online pornography consumers (Kohut et al., 2020). According to a recent study, the lifetime prevalence rates of pornography consumption range from 92% to 98% in males and 50%–91% in females (Ballester-Arnal, Castro-Calvo, García-Barba, Ruiz-Palomino, & Gil-Llario, 2021). The majority of pornography consumers tend to either not perceive notable adverse effects stemming from their engagement with explicit content (Malki, Rahm, Öberg, & Ueda, 2021) or hold positive self-perceptions regarding the outcomes of their pornography consumption (Campbell & Kohut, 2017). For instance, some individuals report gaining insights into broadening their range of sexual behaviors (Kohut, Fisher, & Campbell, 2017), and employing pornography as an educational tool to explore their sexual desires and attain a

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deeper understanding of their sexual identity (McCormack & Wignall, 2017). Although most individuals watch pornography for entertainment purposes without experiencing significant consequences, a minority exhibit problematic pornography use (PPU), characterized by intense impulses or cravings for pornography, difficulty regulating consumption, and persistent engagement despite adverse outcomes (Wéry & Billieux, 2017). In PPU, pornography exerts a powerful influence over an individual's thoughts, feelings, and behaviors, thus assuming a significant role in their life (Wéry, Schimmenti, Karila, & Billieux, 2019). Individuals with PPU may turn to pornography as a way to alleviate negative emotions or cope with stress (Bancroft & Vukadinovic, 2004; Bőthe, Lonza, Štulhofer, & Demetrovics, 2020; Wéry & Billieux, 2016). This leads to a continuous increase in the time dedicated to consuming pornography, despite experiencing conflicts both within themselves and with others (Wéry et al., 2019; Wordecha et al., 2018). Although those with PPU make diligent efforts to reduce or quit pornography usage, the emergence of withdrawal symptoms often results in frequent relapses (Wéry et al., 2019).

The classification of PPU remains controversial (Gola et al., 2022; Gola & Potenza, 2018; Kraus & Sweeney, 2019). PPU is commonly considered the most prevalent manifestation of compulsive sexual behavior disorder (CSBD), categorized as an impulse control disorder in the ICD-11 (WHO, 2019), or as a subtype of hypersexual disorder (Reid et al., 2012). Nonetheless, some scholars argue that it might be more suitable to conceptualize CSBD (including PPU) as a behavioral addiction characterized by essential addictive components (Brand et al., 2020; Kowalewska et al., 2018; Stark, Klucken, Potenza, Brand, & Strahler, 2018). Regardless of its classification, PPU shares similarities with substance use disorders in terms of phenomenology and underlying neurobiological mechanisms (Stark et al., 2018). The dual-process model of addiction proposes that addictive behavior stems from an imbalance between impulsive and reflective systems (e.g., Brand et al., 2019; Zilverstand & Goldstein, 2020). In addiction development, the impulsive system increases the emotional value of drugs while simultaneously reducing the value of natural reinforcers (Robinson & Berridge, 2001). This, in turn, suppresses the reflective system, ultimately leading to a loss of control over drug-driven behaviors (Goldstein & Volkow, 2002). Recent preliminary evidence indicates that individuals with PPU exhibit enhanced cue-reactivity and craving towards sexual stimuli (Gola et al., 2017; Golec, Draps, Stark, Pluta, & Gola, 2021; Voon et al., 2014; Wang, Chen, & Zhang, 2021), as well as impaired executive functioning and response inhibition when processing such stimuli (Seok & Sohn, 2020; Wang & Dai, 2020).

Despite the existing findings, extant studies have primarily emphasized the neurobiological mechanisms associated with PPU, neglecting to thoroughly explore the emotional component (Brand, Snagowski, Laier, & Maderwald, 2016; Gola et al., 2017; Golec et al., 2021; Kühn & Gallinat, 2014; Seok & Sohn, 2015; Voon et al., 2014). These findings highlight the important role of brain reward dysregulation in promoting continuous pornography use among individuals with PPU (Brand et al., 2016; Gola et al., 2017; Golec et al., 2021; for recent reviews, see Klein et al., 2022). Nonetheless, limited knowledge exists regarding the emotional responses of individuals to natural positive and negative reinforcement stimuli in the context of PPU. The majority of the research in this area has not yet explicitly examined how emotional processing mediates PPU.

Evidence suggests that there is a connection between PPU and problems in emotional processing. For instance, studies have shown that emotional dysregulation is related to hypersexuality (Hashemi, Shalchi, & Yaghoubi, 2018) and sexual addiction (Cashwell, Giordano, King, Lankford, & Henson, 2017) (sexual addiction covers addiction to various online and offline sexual behaviors. However, PPU seems to be the most prominent form of sexual addiction (Reid et al., 2012)). Patients with CSBD have been found to employ maladaptive emotional regulation strategies more frequently than healthy controls (HCs; Engel et al., 2019). In addition, emotional dysregulation is thought to be a contributing factor in affecting individuals' self-perceived pornography addiction (Walton, Cantor, Bhullar, & Lykins, 2017). Neuroimaging studies have revealed that prolonged pornography use can have particular impacts on the prefrontal cortex, which is involved in emotional processing and self-regulation of behavior (Brand, Young, & Laier, 2014). Furthermore, PPU is highly comorbid with emotional and mood disturbances, such as anxiety, depression, and impulse control disorder (Burke & MillerMacPhee, 2021; Camilleri, Perry, & Sammut, 2021; Kor et al., 2014; Raymond, Coleman, & Miner, 2003). Research in the field of substance use disorders suggests that individuals with substance addiction may overreact to negative stimuli, and this heightened sensitivity to negative emotions leads them to use substances to alleviate stress (Aguilar de Arcos et al., 2008; Grillon & Baas, 2003). Similarly, the development of PPU could be contributed to negative emotions. Bancroft and Vukadinovic (2004) have identified three possible pathways that may link dysfunctional negative emotions with CSBD, including: a) using sexual activity to fulfill regulatory goals when experiencing negative emotions; b) employing sexual activity to divert attention from external negative stimuli; and c) engaging in sexual arousal as a conditioned response to intense negative emotions.

Moreover, in accordance with the incentive sensitization model proposed by Robinson and Berridge (2001), the emotional component of addiction characterizes an enhancement in the emotional significance of addictive stimuli and a diminished sensitivity to natural positive stimuli. People who experience more positive emotions from drugs tend to seek out these substances to pursue pleasure. Conversely, a reduced level of positive affect towards non-substance-related natural rewards may drive individuals to engage in substance use as a compensatory mechanism to address these deficiencies (Cheetham, Allen, Yücel, & Lubman, 2010). In the same way, the somatic marker theory of addiction assumes that the somatic states (affective representations of past rewards and punishments) controlling decision-making are attenuated when responding to natural rewards and strengthened when responding to addictive stimuli (Bechara, 2003; Verdejo-García & Bechara, 2009). As a result, individuals with addiction may have difficulty replacing addictive behaviors with naturally rewarding ones. Supporting these theories, several studies have found that individuals dependent on opiates (Aguilar de Arcos et al., 2008; Lubman et al., 2009) or individuals dependent on alcohol (Carmona-Perera, Sumarroca-Hernandez, Santolaria-Rossell, Perez-Garcia, & Del Paso, 2019) show reduced responses to pictures of natural rewards. In addition, distinct sensitivities towards monetary rewards compared to non-monetary rewards have been found in individuals with gambling disorder, manifested as an increased sensitivity to addictive cues and a blunted response to non-addictive cues (Sescousse, Barbalat, Domenech, & Dreher, 2013). Similarly, research has indicated that prolonged exposure to pornography can result in a diminished responsiveness of the brain's reward circuitry to natural rewards, including food and social interaction, as well as intimate relationships (Hilton, 2013; Love, Laier, Brand, Hatch, & Hajela, 2015; Wright, Steffen, & Sun, 2019). For example, individuals with greater cue-reactivity to pornography stimuli had less desire for partnered sex (Steele, Staley, Fong, & Prause, 2013). In other words, they preferred artificial stimuli over a very powerful natural reward (partnered sex). It is worth mentioning that the outcomes of many studies in this domain have been intricate due to issues related to causality. The degree to which reduced positive affect precedes drug or pornography use, or results from it, remains not entirely comprehended.

Taken together, the aforementioned evidence highlights the significance of the association between emotional processing and PPU and suggests that individuals with PPU may display deficits in emotional processing. However, their emotional responses to non-addictive positive and negative reinforcement stimuli remains unclear. To the best of our knowledge, only two studies have investigated the relationship between pornographic consumption and emotional responses to everyday emotionally relevant stimuli (Kunaharan, Halpin, Sitharthan, Bosshard, & Walla, 2017; Kunaharan, Halpin, Sitharthan, & Walla, 2020). However, it is important to note that the focus of these two studies was specifically on the relationship between pornography exposure and sexually aggressive behavior. These studies found that people who regularly use pornography display differences in brain responses to unpleasant and violent pictures (Kunaharan et al., 2017, 2020). The present study aims to explore the emotional processing of positive, negative, and neutral images by individuals with PPU and HCs. Due to the complex conscious and unconscious components involved in emotional processing (Koukounas & Over, 2000; Walla, Koller, Brenner, & Bosshard, 2017), we recorded both subjective (valence and arousal) and electrophysiological (event-related potentials, ERPs) responses of the participants to emotional images.

ERPs are commonly used for physiological measurement of emotional responses. Several components of ERPs, occurring in both early and late stages of cognitive processing, demonstrate high sensitivity to the emotional content of stimuli. For example, the fronto-central P2 component, with a peak latency of 100–200 ms following stimulus onset, indicates initial and involuntary visual processing of emotional stimuli (Carretié, 2014). In contrast, the parietal P3 component, which appeared approximately 300 ms after stimulus presentation, may suggest a more intentional processing that relies on the elaborated meaning of stimuli (Hajcak & Foti, 2020). In nonpathological participants, studies consistently observed a greater amplitude of these components in response to emotional than neutral images (Hajcak, Weinberg, MacNamara, & Foti, 2012). Thus, the emotional processing deficit in PPU individuals may correspond to an abnormality in electrophysiological responses.

In real-life scenarios, emotional responses frequently emerge unexpectedly, triggered by sudden stimuli within non-emotional circumstances (Delplanque, Silvert, Hot, & Sequeira, 2005; Yuan et al., 2021). In order to enhance the ecological validity of emotional responses within laboratory conditions, an oddball task was implemented. Within this task, infrequent deviant stimuli encompassing unpleasant, pleasant, and neutral images were presented, while a frequently occurring neutral kettle image was employed as the standard stimulus. This approach aimed to simulate emotional reactivity in the laboratory setting to closely resemble real-world emotional responses. Moreover, this task has been shown to effectively elicit the P2 and P3 components (Olofsson & Polich, 2007).

We hypothesized that PPU participants would exhibit impaired emotional reactions to natural, emotionally relevant pictures in comparison to HCs. Specifically, we expect the following results in participants with PPU compared to HCs: (i) higher subjective ratings (valence and arousal) and larger ERPs amplitudes (P2 and P3 components) in response to unpleasant affective pictures; (ii) lower subjective ratings and reduced ERPs amplitudes in response to pleasant affective pictures.

METHODS

Participants

The sample size for this study was determined using G*Power 3.1.9 (Faul, Erdfelder, Buchner, & Lang, 2009). Due to the paucity of previous relevant studies, a power analysis was conducted using a lower effect size ($f = 0.15$), power of 0.90, and $\alpha = 0.05$, resulting in an estimated sample size of 96. Therefore, 96 participants were selected from a larger pool of 662 male college students who had previously filled out the PPUS and PPCS (refer to Table 1). Further details regarding the identification of careless responses in survey data are provided in the supplementary materials. Due to the lack of official diagnostic criteria

Table 1. Demographic and basic group characteristics

Variables	Min−Max	PPU participants (n = 42)	HCs (n = 45)	t/χ^2	p	Cohen's d
Demographic characteristic						
Age, *M* (*SD*)	18–23	20.14 (1.35)	20.04 (1.45)	0.33	0.744	0.07
Grade, *n* (%)				3.05	0.384	
Freshman		8 (19.0)	15 (33.3)			
Sophomore		16 (38.1)	12 (26.7)			
Junior		7 (16.7)	9 (20.0)			
Senior		11 (26.2)	9 (20.0)			
Emotional characteristic						
SDS, *M* (*SD*)	20–51	39.14 (6.58)	34.58 (6.97)	3.14	**0.002**	0.67
SAS, *M* (*SD*)	24–56	40.24 (9.66)	33.51 (5.51)	4.03	**<0.001**	0.86
Addiction-related characteristic						
PPUS, *M* (*SD*)	0–55	36.79 (9.69)	0.44 (0.62)	25.12	**<0.001**	5.39
PPCS, *M* (*SD*)	18–105	89.90 (9.13)	19.89 (2.64)	49.29	**<0.001**	10.58
IGDS, *M* (*SD*)	9–29	14.71 (6.01)	14.40 (5.07)	0.26	0.792	0.06
PGSI, *M* (*SD*)	0–4	0.26 (0.83)	0.33 (0.93)	−0.38	0.707	0.08

Note. HCs, Healthy Controls; IGDS, Internet Gaming Disorder Scale; PGSI, Problem Gambling Severity Index; PPU, Problematic Pornography Use; PPUS, Problematic Pornography Use Scale; PPCS, Problematic Pornography Consumption Scale; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale.

conceptualizing PPU, the assessment tools for PPU vary among different studies (Fernandez & Griffiths, 2021). In accordance with recommendations from a recent systematic review (Fernandez & Griffiths, 2021) and a comparative analysis of various PPU assessment tools (Chen & Jiang, 2020), this study selected the Problematic Pornography Use Scale (PPUS; Kor et al., 2014) and the Problematic Pornography Consumption Scale (PPCS; Bőthe, Tóth-Király, et al., 2018) for evaluating PPU. The former (PPUS) assesses eight addictive components (such as salience, loss of control, and mood modification), whereas the latter (PPCS) provides a validated cutoff score of 76 (out of 126) for distinguishing between problematic and non-problematic pornography use. These two scales have been well-validated in the Chinese population (Chen et al., 2021; Chen & Jiang, 2020).

PPU participants were identified based on the following criteria for inclusion: (1) scored in the top 20th percentile on the PPUS (Wang & Dai, 2020; Wang et al., 2021); (2) scored higher than 76 on the PPCS (Bőthe, Tóth-Király, et al., 2018). HCs were determined based on the following inclusion criteria: (1) scored in the bottom 20th percentile on the PPUS; (2) scored lower than 76 on the PPCS. All participants were over 18 years of age, heterosexual, right-handed, had no self-reported history of illicit drug use, no Axis-I psychiatric disorder (including major depressive disorder, anxiety disorder, and obsessive-compulsive disorder) as assessed by Mini International Neuropsychiatric Inventory (Sheehan et al., 1998), and no other behavioral addictions, including gaming disorder (scores below 36 on the nine-item short-form Internet Gaming Disorder Scale (IGDS); Pontes & Griffiths, 2015) and gambling disorder (scores below 8 on the Problem Gambling Severity Index (PGSI); Ferris & Wynne, 2001). Women were not included in this study because PPUs are more common among men (Ballester-Arnal et al., 2021; Bőthe, Bartók, et al., 2018; Grubbs, Kraus, & Perry, 2019; Lewczuk, Glica, Nowakowska, Gola, & Grubbs, 2020), and gender differences regarding emotional processing have been documented (e.g., McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008). Among them, nine participants (six PPU participants and three HCs) were excluded due to excessive eye movement artifacts during the recording of ERPs. Ultimately, the sample consisted of 42 PPU participants and 45 HCs.

Questionnaire assessments

PPUS. The PPUS comprises 12 items that are categorized into four dimensions, namely distress and functional problems, overuse, difficulty in controlling, and coping with negative emotions. A Likert scale with 6 point was used, with responses ranging from "0 = never" to "5 = always". The Cronbach's alpha coefficient for the total scale was 0.98.

PPCS. The PPCS includes 18 items, divided into six dimensions, including salience, mood modification, conflict, tolerance, relapse, and withdrawal. Responses were recorded on a 7-point Likert scale, ranging from "1 = never" to "7 = always". A total score above 76 indicates PPU. The Cronbach's alpha coefficient for the total scale was 0.93.

Measures of emotional and other addictions. The Self-Rating Depression Scale (SDS; Zung, Richards, & Short, 1965) and the Self-Rating Anxiety Scale (SAS; Zung, 1971) were used to evaluate the level of depression and anxiety, respectively. Both the SDS and SAS encompass 20 items, employing a 4-point rating scale ranging from 1 (none, or a little of the time) to 4 (most, or all of the time) for the assessment of emotional experiences during the preceding week. In both scales, the total score ranges from 20 to 80, with higher scores indicating elevated levels of depression or anxiety. In this study, the Cronbach's alpha coefficient for the SDS and SAS were 0.80 and 0.86, respectively. Additionally, the IGDS (Pontes & Griffiths, 2015) and PGSI (Ferris & Wynne, 2001) were respectively used to assess gaming disorder and gambling disorder. The IGDS is a concise psychometric instrument derived from the nine fundamental criteria defining gaming disorder as per the DSM-5. It consists of nine items, with respondents providing answers on a 5-point Likert scale ranging from 1 (never) to 5 (very often). Total scores are calculated by summing the participant's responses, ranging from 9 to 45. Participants who score a minimum of 36 out of 45 points on the test are classified as having a gaming disorder. The PGSI contains nine items. Responses were scored using a 4-point Likert scale, with 0 indicating never and 3 indicating almost always. The scores from these items are summed, and a total score of 0 identifies a non-gambler, 1–2 identifies a low-risk gambler, 3–7 identifies a moderate-risk gambler, and 8 or more identifies a problem gambler. In this study, the Cronbach's alpha coefficient for the IGDS and PGSI were 0.91 and 0.67, respectively.

Procedure

Screening questionnaires were distributed through Wenjuanxing (www.sojump.com), a popular survey platform in China. Participants who had engaged in pornography use at least once in the past six months were recruited and asked to fill out the questionnaire by scanning a QR code to log in. Based on the PPU screening criteria described above, potential PPU participants and HCs were assessed through a structured psychiatric interview conducted by a psychiatrist to exclude Axis I psychiatric disorders. Moreover, no participants reported a history of substance abuse or dependence. Only participants who met the screening criteria and did not have any of the previously mentioned disorders were invited to participate in the subsequent ERPs study (Fig. 1).

Stimuli and experimental task

We employed a modified oddball paradigm in this study, which included four blocks with 100 trials each (70% standard vs 30% deviant pictures). The standard picture was a picture of kettle, which remained unchanged throughout the experiment. Sixty deviant pictures were selected from the Chinese Affective Picture System (Bai, Ma, Huang, & Luo, 2005) (The numbers of the selected pictures are presented in the supplementary materials). These pictures were arranged to form three conditions (20 pleasant, 20 unpleasant, and 20 neutral) based on valence and arousal norms. Mean valence and arousal ratings were 7.27 and 5.72 for the pleasant picture set, 2.23 and 5.84 for the unpleasant picture set, 5.14 and 2.41 for the neutral picture set, respectively. Ten images

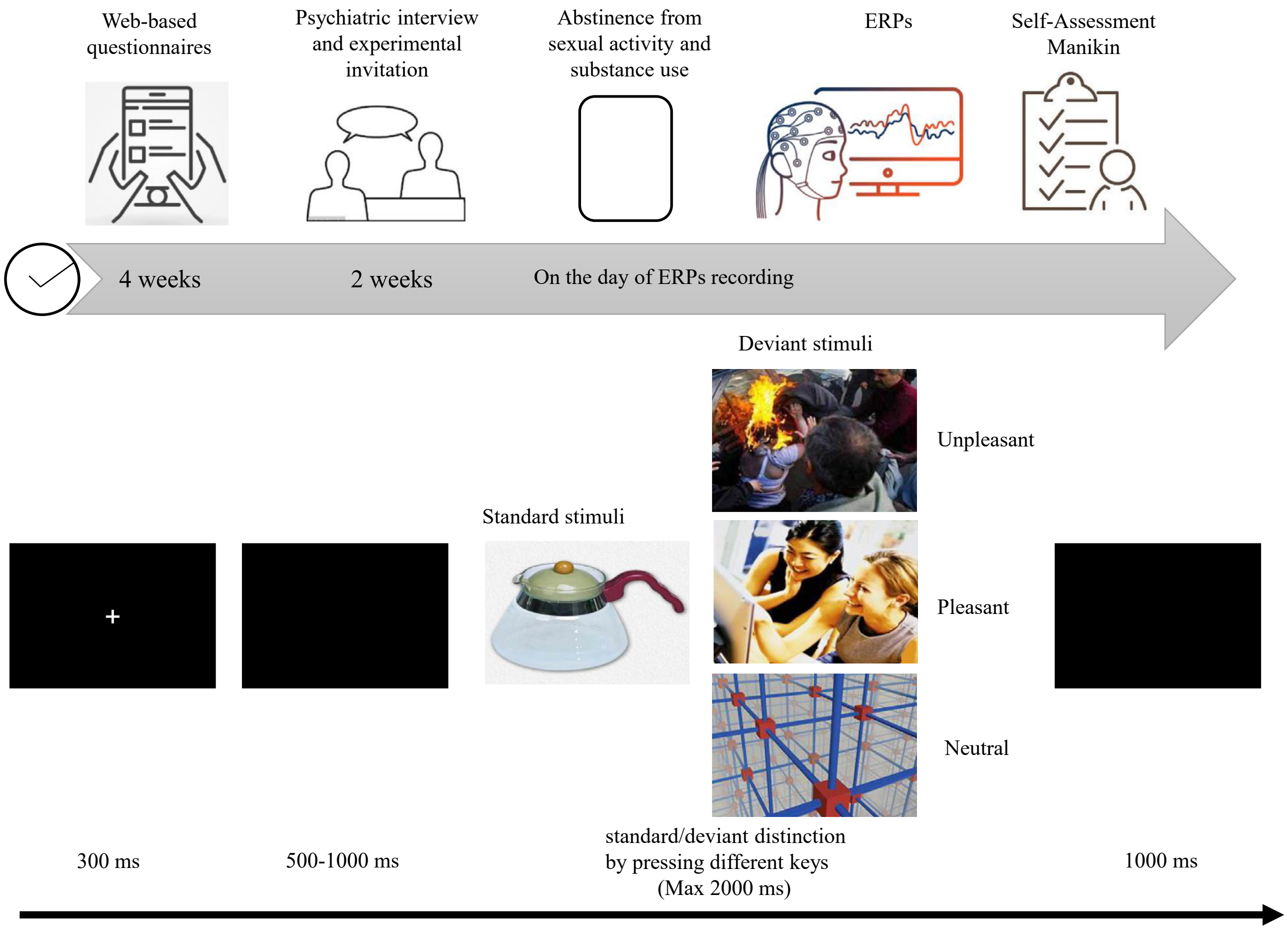

Fig. 1. Data collection (top) and experimental procedure (bottom)

of each condition were presented for each block, with each image repeated twice.

In Fig. 1, it is illustrated that each trial starts with a 300 ms fixation cross, which is then succeeded by a variable-duration blank screen (lasting between 500 and 1000 ms). Afterwards, a 2000 ms image is displayed, and participants were instructed to respond with speed and accuracy by pressing either the "F" key for standard stimuli or the "J" key for deviant stimuli. The intertrial interval was 1000 ms. The images were presented in a random order, and the assignment of keys was counterbalanced across all participants. Prior to starting the formal experiment, participants completed 10 practice trials to familiarize themselves with the task. The standard image used during the practice phase was identical to the one employed in the formal experiment. In contrast, the deviant stimuli consisted of neutral pictures that were not displayed in the subsequent experiment.

Electrophysiological recording and analysis

In this study, EEG activity was recorded utilizing a 64-scalp site elastic cap, which contained active tin electrodes. The BrainAmp amplifier (Brain Products GmbH, München, Germany) was used to amplify the EEG signals. Reference electrodes were positioned on the left and right mastoids, while the ground electrode was placed on the medial frontal aspect. The right eye was utilized to record vertical electro-oculograms (EOGs). All electrode impedance was maintained below 5 kΩ. Brain Vision Analyzer 2.0 was used for offline data analysis. Bandpass filtering with settings of 0.01–30 Hz (24 dB/oct) was carried out. Independent component analysis based on EEG channels was conducted with Meaned Slope Algorithm to remove ocular artifacts. The ocular artifacts were detected by visual inspection of the topographies. Other artifacts (e.g., muscular/movement) are automatically detected and excluded based on the following criteria: (1) maximum allowed voltage step exceeds 50 μV/ms; (2) maximum allowed absolute difference exceeds 100 μV within a 200 ms interval. The mean number of trials for unpleasant, pleasant, and neutral conditions were 35.59 (SD = 6.84), 35.72 (SD = 7.16), and 35.68 (SD = 6.26), respectively.

To generate ERPs, the EEG data for accurate responses in each condition was combined and averaged. The epoch was set at 800 ms, which included a 200 ms baseline period before the stimulus onset. Based on a visual inspection of the grand average ERP and previous research (e.g., Nijs, Franken, & Muris, 2010; Prause, Steele, Staley, Sabatinelli, & Hajcak, 2015; Wang et al., 2021), the P2 component was defined as the average amplitude in the 150–220 ms time range, while the P3 component was defined as the average amplitude in the 300–500 ms time range. The fronto-central P2 was measured at electrode sites F3, Fz, F4, FC3, FCz, FC4, C3, Cz, and C4, while the parietal P3 was measured at electrode sites C3, Cz, C4, CP3, CPz, CP4, P3, Pz, and P4. This electrode selection aligns with previous studies investigating P2 and P3 components (e.g., Dai, Ma, & Wang, 2011; Prause et al., 2015; Wang & Dai, 2020; Wang et al., 2021).

Post-experiment rating of emotion

After acquiring the EEG data, the Self-Assessment Manikin (SAM; Bradley & Lang, 1994) was utilized for emotional evaluation, for determining participants' subjective emotional states evoked by each image within the three emotional categories. The participants were asked to rate the affective valence and arousal using a scale of 1–9. The valence ratings ranged from unpleasant (1) to pleasant (9) and the arousal ratings ranged from relaxed (1) to aroused (9). The presentation sequence of the pictures was randomized across the emotion conditions.

Statistical analyses

SPSS 22.0 software (SPSS, Chicago, USA) was used for statistical analysis. The questionnaire data were analyzed using independent sample t-tests. For the behavioral measures (accuracy, RT, and emotional ratings), a 2 × 3 repeated-measures analysis of variance (ANOVA) was employed.[1] Group (comprising PPU participants and HCs) was treated as a between-subjects factor, while Picture type (including unpleasant, pleasant, and neutral) was treated as a within-subjects factor. For ERPs data (average amplitudes of P2 and P3), in addition to the variables of Group and Picture type, there are also two within-subject variables: Laterality (left, central, and right) and Site. For P2, the sites are frontal, frontal-central, and central, while for P3, the sites are central, central-parietal, and parietal. Post-hoc analyses using pairwise comparisons with Bonferroni adjustments were conducted. To account for degrees of freedom, Greenhouse-Geisser correction was applied. Effect sizes were calculated using Cohen's d and partial eta squared (η_p^2).

Ethics

The study adhered to the ethical guidelines set forth in the Declaration of Helsinki. Participants provided written informed consent. The research protocol was reviewed and approved by the local Ethical Review Board to ensure compliance with ethical standards.

RESULTS

Questionnaire results

Descriptive statistics for questionnaire data are presented in Table 1. As expected, PPU participants scored higher than HCs on both PPUS and PPCS. In addition, PPU participants had higher scores on anxiety and depression compared to HCs. There were no significant differences between the two groups on other variables.

[1]Due to significant between-group differences observed in anxiety and depression scores, we also conducted an analysis of covariance (ANCOVA) on behavioral and ERPs data. The results indicated that the main findings remained unchanged. Please refer to Supplementary Material (Table S1) for the results of the ANCOVA.

Behavioral results: RT and accuracy

For RT, the main effect of Picture type was significant, F (1, 85) = 6.26, p = 0.004, η_p^2 = 0.07. All participants responded significantly faster to unpleasant (589.65 ± 110.37 ms) and pleasant (588.64 ± 107.98 ms) pictures than to neutral (606.76 ± 127.59 ms) pictures. This was expected because neutral pictures and standard pictures belong to the same stimulus category, making it more difficult for participants to classify them into different keys. Neither the main effect of Group [F (1, 85) = 2.83, p = 0.096, η_p^2 = 0.03] nor the Group × Picture type interaction [F (1, 85) = 0.26, p = 0.734] was significant. No significant differences were found in correct rates (96.50% overall).

Behavioral results: subjective ratings

There were significant main effects of Group [F (1, 85) = 17.64, p < 0.001, η_p^2 = 0.17] and Picture type [F (2, 170) = 397.96, p < 0.001, η_p^2 = 0.82] in terms of subjective ratings of valence. Pleasant pictures scored significantly higher than neutral pictures (p < 0.001) in terms of pleasantness scores, which in turn scored significantly higher than unpleasant pictures (p < 0.001). Moreover, the Group × Picture type interaction was significant, F (2, 170) = 3.69, p = 0.041, η_p^2 = 0.04 (see Table 2 and Fig. 2). Post-hoc analyses were employed to examine possible differences between the groups on each emotional condition. The results showed a significant group difference in the unpleasant

Table 2. Mean and standard deviations (in brackets) of SAM ratings and ERPs amplitudes evoked by the three picture categories for PPU participants and HCs

	PPU participants (n = 42)			HCs (n = 45)		
	Unpleasant	Pleasant	Neutral	Unpleasant	Pleasant	Neutral
Valence	2.08 (1.04)	6.60 (1.31)	5.13 (0.75)	2.90 (1.10)	7.00 (0.72)	5.11 (0.52)
Arousal	5.92 (2.25)	5.97 (1.58)	2.66 (1.18)	6.24 (1.90)	5.95 (1.65)	2.54 (1.03)
P2	−2.19 (4.48)	−3.18 (3.85)	−3.72 (3.46)	−3.33 (4.64)	−3.51 (4.07)	−3.42 (3.80)
P3	5.37 (4.30)	3.64 (3.85)	3.07 (3.53)	6.07 (4.87)	4.79 (4.43)	2.73 (3.70)

Note. ERPs, Event-related Potentials; HCs, Healthy Controls; PPU, Problematic Pornography Use; SAM, Self-Assessment Manikin.

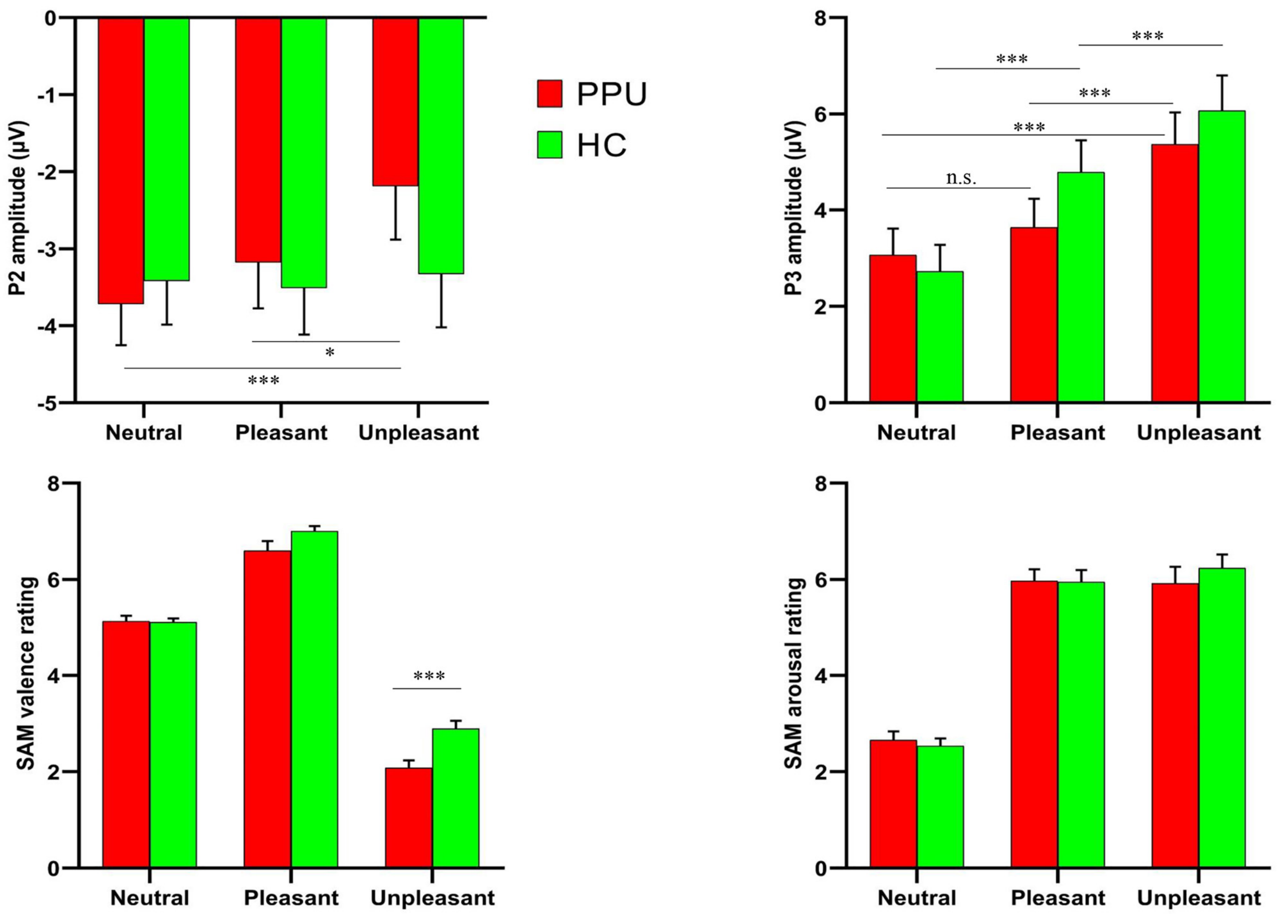

Fig. 2. Self-Assessment Manikin (SAM) ratings and ERPs amplitudes by the three picture categories for PPU participants and HCs. Error bars represent one standard error

image condition, F (1, 85) = 12.60, $p < 0.001$, $\eta_p^2 = 0.13$, with PPU participants (2.08 ± 1.04) reporting lower pleasantness scores than HCs (2.90 ± 1.11). However, group differences were not significant in the pleasant images [F (1, 85) = 3.23, $p = 0.076$, $\eta_p^2 = 0.04$] and neutral images ($F < 1$). For the subjective ratings of arousal, only a significant main effect of Picture type was found, F (2, 170) = 146.55, $p < 0.001$, $\eta_p^2 = 0.63$. Pleasant (5.96 ± 1.61) and unpleasant images (6.08 ± 2.07) did not differ in arousal scores, and both were rated as more arousing than neutral images (2.60 ± 1.10).

ERPs results

In this section, only the most important results are reported. Please refer to the Supplementary Materials (Tables S2 and S3) for complete statistical results.

P2. The main effect of Picture type was significant, F (2, 170) = 5.45, $p = 0.006$, $\eta_p^2 = 0.06$. Although there were no significant differences in the P2 amplitudes between unpleasant and pleasant pictures ($p > 0.10$), as well as between pleasant and neutral pictures ($p > 0.97$), the P2 amplitude elicited by unpleasant pictures was significantly greater (i.e., more positive going) than that elicited by neutral pictures ($p = 0.007$). In addition, there was a significant Group × Picture type interaction, F (2, 170) = 4.09, $p = 0.02$, $\eta_p^2 = 0.05$ (see Figs 2–4). The simple-effect analysis of Picture type revealed a significant main effect for PPU participants [F (2, 82) = 10.34, $p < 0.001$, $\eta_p^2 = 0.20$] rather than HCs [F (2, 88) = 0.11, $p > 0.88$, $\eta_p^2 = 0.003$]. Pair-wise comparisons showed that for PPU participants, unpleasant images evoked larger P2 amplitudes than pleasant ($p = 0.032$) and neutral ($p < 0.001$) images, although the latter two did not differ ($p > 0.24$). Furthermore, the simple-effect analysis of Group indicated that there were no significant differences in P2 amplitude across all three image types for both groups ($Ps > 0.24$).

P3. The main effect of Picture type was significant, F (2, 170) = 66.91, $p < 0.001$, $\eta_p^2 = 0.44$. Unpleasant images evoked larger P3 amplitudes than pleasant images ($p < 0.001$), which in turn evoked larger P3 amplitudes than neutral images ($p < 0.001$). More importantly, the Group × Picture type interaction was significant, F (2, 170) = 4.92, $p = 0.009$, $\eta_p^2 = 0.06$ (see Figs 2–4). The simple-effect analysis of Picture type revealed a significant main effect for both PPU participants [F (2, 82) = 25.44, $p < 0.001$, $\eta_p^2 = 0.38$] and HCs [F (2, 82) = 45.89, $p < 0.001$, $\eta_p^2 = 0.51$], but with different patterns. For HCs, unpleasant images evoked larger P3 amplitudes than pleasant images ($p < 0.001$), which in turn evoked larger P3 amplitudes than neutral images ($p < 0.001$). For PPU participants, unpleasant images evoked larger P3 amplitudes than both pleasant ($p < 0.001$) and neutral ($p < 0.001$) images, with no difference between the latter two conditions ($p > 0.25$). Furthermore, the simple-effect analysis of Group indicated that there were no significant differences in P3 amplitude across all three image types for both groups ($Ps > 0.19$).

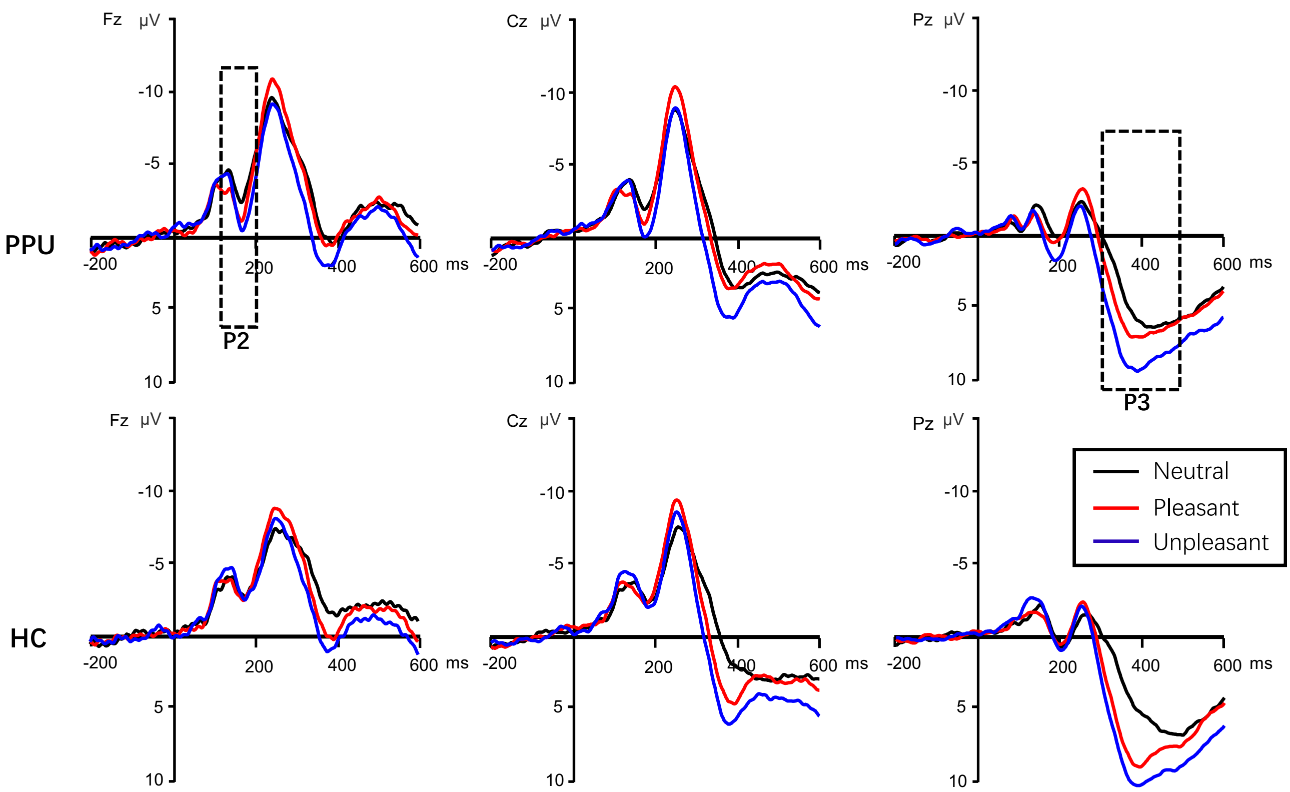

Fig. 3. Grand average ERPs for the PPU participants and HCs under the unpleasant, pleasant, and neutral conditions for electrodes sites at Fz, Cz, and Pz

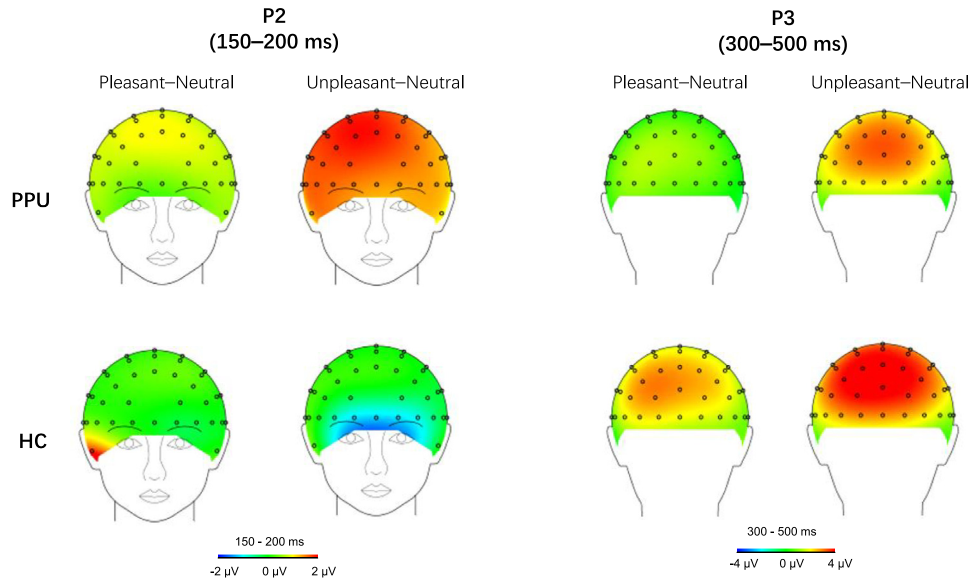

Fig. 4. Topographical maps of the amplitudes difference between emotional and neutral conditions (across 150–200 and 300–500 ms) in PPU participants and HCs

DISCUSSION

The primary objective of this study was to investigate the hedonic responses to non-addiction related emotional stimuli in individuals with PPU. Across both electrophysiological and subjective response measures, consistent findings revealed aberrant emotional processing patterns among PPU participants compared to HCs. In terms of subjective measures, PPU participants reported lower valence ratings for unpleasant images compared to HCs. Regarding electrophysiological measures, PPU participants reported larger P2 amplitudes for unpleasant pictures compared to both pleasant and neutral pictures. Furthermore, while HCs displayed an enhanced P3 response to pleasant images relative to neutral images, no such differentiation was evident in PPU participants. These collective findings indicate that individuals with PPU exhibit abnormal emotional processing patterns, characterized by heightened reactivity to negative stimuli and diminished responsiveness to positive stimuli.

Enhanced responses to negative stimuli

In the present study, PPU participants reported larger P2 amplitudes for unpleasant pictures compared to both pleasant and neutral pictures. The P2 component reflects the early allocation of attentional resources (Carretié, 2014). Enhanced P2 amplitudes for emotional expressions relative to neutral expressions were reported (Carretié et al., 2013). Therefore, this finding suggests that during relatively early stages of stimulus processing, individuals with PPU allocate more attentional resources to negative stimuli, reflecting an enhanced sensitivity to these stimuli in their motivational system. However, it is worth noting that in the late stage of emotional processing, both PPU participants and HCs demonstrated larger P3 amplitudes in response to unpleasant images compared to pleasant and neutral images. The P3 signals the cognitive assessment of the meaning of stimuli (Ito, Larsen, Smith, & Cacioppo, 1998). This cognitive assessment involves a conscious and regulated process in which the importance of emotional information is appraised. Due to the biological significance of negative stimuli, both groups exhibited heightened reactions to negative images in higher cognitive stages, which may reflect a negative bias in human emotions (Cacioppo & Gardner, 1999; Ito et al., 1998).

The findings of heightened emotional reactivity to unpleasant images in the early stages of emotional processing aligns with previous evidence in the field of substance use disorder. Previous studies have demonstrated that people with substance use difficulties tend to exhibit an excessive reaction to negative stimuli (Aguilar de Arcos et al., 2008; Grillon & Baas, 2003), and this heightened sensitivity to negative stimuli leads individuals to use addictive substances as a means to alleviate negative emotions (Cheetham et al., 2010). Models of tension reduction or self-medication theory postulate that potential addictive behaviors may regulate negative emotional states or reduce stress through negative reinforcement mechanisms (Gola & Potenza, 2016; Koob & Moal, 1997). In a similar vein, the compensatory Internet use theory (Kardefelt-Winther, 2014) suggests that certain individuals may turn to online environments as a coping mechanism for relieving negative emotions resulting from stressful or unfavorable life circumstances. This maladaptive coping strategy could potentially lead to problematic use or addiction. Therefore, individuals with a tendency to experience heightened negative emotions carry a higher vulnerability to addiction (Bonnaire & Baptista, 2019; Yuan, Elhai, & Hall, 2021). However, no significant intergroup differences were observed in the amplitudes of the P2 and P3 components, which might be attributed to inadequate sample size. Therefore, further research is warranted.

On the other hand, the present findings may underlie the personality traits of individuals with PPU or CSBD characterized by mood and anxiety disorders (Lew-Starowicz, Lewczuk, Nowakowska, Kraus, & Gola, 2020). Some studies have shown a high comorbidity rate between CSBD and mood and anxiety disorders (e.g., Berberovic, 2013; Engel et al., 2019; Kafka & Prentky, 1994; Kuzma & Black, 2008; Raymond et al., 2003; Schultz, Hook, Davis, Penberthy, & Reid, 2014). A recent study has revealed that men with CSBD exhibit a range of maladaptive personality traits on the Personality Inventory for DSM-5, such as negative affect and detachment (Engel et al., 2023). Aligning with previous research, the current study revealed that participants experiencing PPU exhibited elevated levels of anxiety and depression when compared to HCs. According to prior research, individuals with anxiety or depression demonstrate an augmented attentional bias towards negative stimuli, which plays a significant role in the maintenance and exacerbation of their anxiety or depressive states (Mogg & Bradley, 2005). These findings suggest that heightened sensitivity to negative stimuli and the resulting elevated levels of anxiety or depression may serve as underlying driving forces in the development of PPU symptoms.

Blunted responses to positive stimuli

In contrast to unpleasant stimuli, PPU participants showed a blunted processing of pleasant stimuli. In the HCs, we observe the arousal and valence effects commonly found in emotion studies involving nonpathological participants (Hajcak et al., 2012; Olofsson & Polich, 2007). Specifically, they exhibit larger P3 amplitudes in response to emotional stimuli compared to neutral stimuli, indicating an arousal effect. Furthermore, they show larger P3 amplitudes for negative stimuli compared to positive stimuli, reflecting a valence effect. These effects were attributed to the heightened cognitive processing of emotional stimuli (Olofsson & Polich, 2007). However, this specific phenomenon observed in HCs exhibits different characteristics in individuals with PPU. Although PPU participants demonstrated greater P3 amplitudes in response to negative images compared to both positive and neutral images, no significant differences were observed between positive and neutral images. The absence of an enhanced P3 response to pleasant stimuli can be regarded as an indicator of diminished motivational salience, indicating a reduced attention to natural rewards (Robinson & Berridge, 2001; Verdejo-Garcia, Pérez-García, & Bechara, 2006). These results are in line with previous research conducted on individuals with opioid use disorder (Aguilar de Arcos et al., 2008), individuals with alcohol use disorder (Carmona-Perera et al., 2019), and individuals with pathological gambling (Sescousse et al., 2013), indicating a blunted response to natural rewards. These results also align with previous neuroimaging studies indicating decreased activation in emotional regions of the brain among individuals with drug addiction when exposed to positive stimuli, coupled with heightened activation in response to drug-related stimuli (Garavan et al., 2000; Wexler et al., 2001). However, the findings of this study are inconsistent with several previous research findings in the domain of PPU. For instance, Banca et al. (2016) found that compared to HCs, individuals with CSBD showed a generalized preference for cues conditioned to sexual and monetary versus neutral outcomes. Furthermore, two fMRI studies discovered that both individuals with PPU/CSBD and HCs exhibited similar ventral striatal and orbitofrontal cortex responses to cues predicting monetary rewards during the reward anticipation stage (Gola et al., 2017; Golec et al., 2021). The disparity in these results underscores the necessity for additional research. However, it is worth noting that unlike the monetary rewards employed by previous studies (Banca et al., 2016; Gola et al., 2017; Golec et al., 2021), the pleasant emotional images utilized in our study belong to the category of social rewards. Previous research has demonstrated a clear division in the phenomenology and neurobiology of monetary and social rewards processing (Goerlich et al., 2017; Morelli, Sacchet, & Zaki, 2015). As such, an interesting avenue for future research would be to investigate whether the influence of PPU on reward processing diverges depending on the specific reward category.

It has been suggested that the sensitization of the motivational circuits towards addiction-related stimuli may be linked to the emotional response of craving (Goldstein & Volkow, 2002), which could also lead to a suppression of the emotional response to other natural reinforcers unrelated to addiction (Robinson & Berridge, 2001), as indicated by the findings of this study. In addition, studies underscore the impact of emotional markers on decision-making among individuals with addiction (Bechara, 2003; Verdejo-García & Bechara, 2009). Individuals with addiction exhibit a decision-making deficit characterized by an overestimation of the positive emotional markers attached to addictive behaviors, coupled with a diminished emotional value assigned to other natural rewards. Thus, the findings of this study provide insights into the potential mechanisms underlying the persistent and repetitive engagement in online sexual activity among individuals with PPU, highlighting the difficulty of substituting these behaviors with other adaptive alternatives.

Theoretical and practical implications

The results of this study have theoretical and practical significance. Although many scholars have emphasized the role of emotional processing and regulation in conceptualizing and diagnosing PPU and CSBD (Bancroft & Vukadinovic, 2004; Kafka, 2010), the current diagnostic criteria listed in ICD-11 do not specifically highlight the role of emotions. Consistent with this, current research focuses primarily on the neurobiological mechanisms associated with PPU or CSBD, such as craving for pornographic stimuli, rather than on the emotional experiences related to other natural reinforcers. This study represents one of the first attempts to investigate the emotional experiences of individuals with

PPU in relation to natural emotional stimuli. It contributes to raising awareness about the crucial role of emotional regulation in the conceptualization of PPU or CSBD. Furthermore, the results of this study are consistent with clinical observations of patients with PPU, who frequently report a sense of emptiness and boredom in their everyday emotional experiences, including their family dynamics, intimate relationships, and sexual life (Efrati & Gola, 2018; Engel et al., 2023; Steel et al., 2013; Weber et al., 2018). This study implies that it is crucial to incorporate non-pornographic natural reinforcers into future clinical practices for interventions and treatment of PPU. By enhancing the value of these natural stimuli and increasing the sensitivity of individuals with PPU to them, new avenues for reinforcement can be established.

Limitations and directions for future research

Several noteworthy limitations should be acknowledged, pointing towards potential directions for future research. Firstly, a prominent problem of this study is the inability to establish causality. Whether increased sensitivity to negative stimuli as well as decreased sensitivity to positive stimuli is a consequence of long-term pornography use, or whether it represents a predisposing factor for addictive disorders, remains unclear. Future research endeavors may benefit from employing longitudinal study designs or drawing insights from vulnerability models used in the study of substance use disorders (Verdejo-García, Lawrence, & Clark, 2008). These approaches could help address the question of causality and shed light on the complex relationship between long-term pornography use, susceptibility factors, and their interplay. Secondly, although it is well-established in the literature that an overvaluation of addiction-related stimuli hijacks hedonic responses to other rewards, it is worth noting that the current study did not incorporate sexual-related stimuli. Future studies should include pornography stimuli to determine whether the blunted response to positive stimuli is accompanied by an enhanced response to pornographic stimuli. Thirdly, our investigation was conducted using a non-clinical sample of college students. Indeed, due to the absence of standardized clinical diagnostic criteria, it remains challenging to definitively identify patients with PPU. However, future research efforts should still consider utilizing clinical samples, such as individuals diagnosed with CSBD, to replicate the findings of this study and validate its conclusions. Fourthly, given the higher prevalence of PPU in males, this study excluded female participants. Previous studies using nonpathological participants have highlighted significant gender differences in emotional processing (e.g., McRae et al., 2008). Therefore, further investigation is warranted to ascertain the generalizability of the emotional processing patterns observed in male PPU individuals in this study to female populations. Finally, although participants did not report a history of substance abuse or dependence, this study did not measure their substance use behaviors, such as cigarette and alcohol consumption. As a result, the potential influence of substance use has not been fully ruled out.

CONCLUSION

In conclusion, the heightened reactivity to negative stimuli and diminished responsiveness to positive stimuli may indicate a common emotional processing profile in individuals with PPU. The increased sensitivity to negative stimuli may drive their engagement in pornography as a means of stress regulation, while the decreased sensitivity to positive stimuli makes it challenging for them to find alternative natural reinforcers to overcome their addictive behaviors. These findings hold significant implications for PPU interventions, emphasizing the importance of addressing the motivational salience of natural reward in daily life in order to potentially enhance emotional processing.

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SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1556/2006.2023.00058.

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