Emotional Processing Abnormalities in Online Gaming Addiction

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Abstract

Research indicates that individuals with Internet Gaming Disorder (IGD) exhibit abnormal processing biases toward negative emotional stimuli, particularly angry emotional stimuli. Moreover, IGD individuals display excessive emotional arousal in response to negative stimuli and encounter difficulties in regulating negative emotions. These abnormalities in emotional processing capabilities play a significant role in the maintenance and development of IGD. Concurrently, brain regions associated with emotional processing in IGD individuals also show abnormalities, including the amygdala, anterior cingulate cortex, insula, and portions of the prefrontal cortex. Future research could further investigate group emotional processing in IGD, the temporal dynamics of emotional processing, effective methods for enhancing emotion regulation abilities in IGD individuals, and emotional processing issues in adolescents with IGD. Additionally, diversified settings and presentations of emotional stimuli can be employed to achieve various research objectives, while it is also essential to consider the influence of participants' gender ratio and their long-term versus short-term emotional states on emotional processing research outcomes.

Full Text

Abnormal Emotional Processing in Individuals with Internet Gaming Disorder

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Abstract: Research indicates that individuals with Internet Gaming Disorder (IGD) exhibit abnormal processing biases toward negative emotional stimuli,

particularly those conveying anger. These individuals also demonstrate excessive emotional arousal when confronted with negative stimuli and encounter difficulties in regulating negative emotions. Such abnormalities in emotional processing capacity play a crucial role in the maintenance and development of IGD. Concurrently, anomalies have been observed in brain regions associated with emotional processing in IGD, including the amygdala, anterior cingulate cortex, insula, and portions of the prefrontal cortex. Future research should place greater emphasis on group emotional processing in IGD, the temporal dynamics of emotional processing, effective methods for enhancing emotion regulation abilities in individuals with IGD, and emotional processing issues in adolescents with IGD. Additionally, employing diverse designs and presentations of emotional stimuli can serve different research purposes, while researchers must also consider how participants' gender ratios and both long-term and short-term emotional states may influence emotional processing study outcomes.

Keywords: Internet Gaming Disorder (IGD), facial expression, emotional processing bias, emotion regulation

1 Introduction

Online gaming has become an immensely popular internet activity. As of June 2023, China had 550 million online gaming users, accounting for 51.0% of all internet users (China Internet Network Information Center, 2023). While the rise of various online games enriches people' s entertainment lives, it also brings negative consequences. Previous research has demonstrated that Internet Gaming Disorder (IGD) leads to problems in physical and mental health, work, academic performance, interpersonal relationships, and family dynamics (Paulus et al., 2018; Sugaya et al., 2019). In 2013, the American Psychiatric Association included IGD in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), emphasizing the need for further empirical research to obtain more information about IGD. Subsequently, in 2018, the World Health Organization also included gaming disorder as a mental health condition in the 11th revision of the International Classification of Diseases (ICD-11). These developments underscore that IGD has garnered increasing attention from the international community, making research on IGD more urgent and important.

The DSM-5 defines IGD as persistent and recurrent use of the internet to engage in games, typically with other players, resulting in clinically significant impairment or distress. Recent epidemiological studies from various countries indicate that the prevalence of IGD ranges from approximately 2% to 6% (Almutairi et al., 2023; Biolcati et al., 2021; Chiu et al., 2018; Carlisle, 2020; Fam, 2018; Laconi et al., 2017; Siste et al., 2021; Yu & Cho, 2017). Generally, the prevalence is higher among males than females (Carlisle, 2020; Fam, 2018; Yu & Cho, 2017), and the proportion of IGD is higher among minors than adults (Fam, 2018; Laconi et al., 2017; Siste et al., 2021; Yu & Cho, 2017; Zengin et al., 2021). One meta-analysis even found that IGD accounted for 9.9% of 407,620 adolescents and young adults from 33 countries (Gao et al., 2022). Previous studies have

shown significant correlations between more severe antisocial behavior, anger control problems, and parental anxiety and depression with IGD (Wartberg et al., 2017; Wartberg et al., 2019). Meanwhile, individuals with IGD often exhibit more severe depression and anxiety (Ohayon & Roberts, 2021; Ostinelli et al., 2021). Thus, research on IGD is crucial for safeguarding the physical and mental health of minors (Imataka et al., 2022; Sugaya et al., 2019).

Research on IGD can be traced back to studies on gambling addiction, and its current diagnostic criteria draw from various aspects of gambling addiction, internet addiction, and substance addiction (Feng et al., 2017; Shapira et al., 2000; Shapira et al., 2003). However, the assessment of IGD has remained controversial for many years (Jin et al., 2019), with numerous scales available for evaluating IGD (Mihara & Higuchi, 2017) and no unified standard for screening participants (Dong et al., 2020). As a type of behavioral addiction, IGD differs from drug addiction in that its formation does not involve prolonged direct stimulation from external substances, yet its addictive manifestations and brain mechanism changes share similarities with substance addiction, including in emotional processing, as confirmed by several studies (Ceceli et al., 2022; Crunelle et al., 2015; Foisy et al., 2007; Mueller et al., 2017; Yao et al., 2017; Yip et al., 2018).

Based on existing research, individuals with IGD exhibit abnormal processing biases toward negative emotional stimuli, particularly angry expressions, and show excessive emotional arousal when facing negative stimuli while struggling to regulate these emotions effectively. Furthermore, numerous studies using positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and voxel-based morphometry (VBM) have identified abnormalities in brain regions related to emotional processing in IGD, such as the amygdala, anterior cingulate cortex (ACC), insula, and portions of the prefrontal cortex (PFC) (Kuss et al., 2018; Lee et al., 2018; Niu et al., 2022; Qin et al., 2020; Tian et al., 2014; Zhou et al., 2017). Moreover, as a subclass of internet addiction, the emotional processing abnormalities exhibited by individuals with IGD differ from other subclasses of internet addiction. Ünal-Aydin et al. (2020) found that social networking addiction was associated with poorer performance in recognizing negative emotions compared to non-addicted individuals, a finding contrary to results showing abnormal processing biases toward negative emotional stimuli in IGD. Additionally, in Rogier and Velotti' s (2018) emotion regulation model for gambling disorder, positive emotion dysregulation may play a central role, whereas existing research indicates that individuals with IGD experience difficulties regulating negative emotions, suggesting that emotional regulation abnormalities in internet gambling addiction may differ from those in IGD. These findings demonstrate that emotional processing abnormalities in IGD are unique, and investigating their relationship can provide more targeted scientific evidence for improving emotional processing capacity and developing interventions for individuals with IGD.

Based on research findings in the field of IGD and emotional processing, abnor-

malities can be categorized into two aspects: abnormal processing bias toward negative emotional stimuli and difficulties in negative emotion regulation. The abnormal processing bias toward negative emotional stimuli manifests in two areas: facial expression processing in facial expression recognition tasks and processing of emotional distractors in executive control tasks.

2.1 Abnormal Processing Bias Toward Angry Facial Expressions in Facial Expression Recognition Tasks in IGD

Earlier studies found that typical participants recognized happy faces faster than angry faces (Billings et al., 1993). However, Kirsh and Mounts (2007) discovered the opposite phenomenon in participants with short-term exposure to violent video games, terming this "decreased happy face advantage." Recent research in IGD has also employed the Japanese and Caucasian Brief Affect Recognition Test (JACBART) to investigate micro-expression processing. Fan et al. (2022) found that compared to control groups, individuals with IGD recognized angry micro-expressions more accurately than happy micro-expressions, with more lenient criteria and greater sensitivity to angry micro-expressions (Fan et al., 2023). The researchers concluded that individuals with IGD exhibit a recognition bias toward negative micro-expressions (Fan et al., 2022; Fan et al., 2023). However, Peng et al. (2017) reported different findings. Their behavioral results showed that individuals with IGD responded more slowly to sad expressions than controls but not to happy expressions. Meanwhile, EEG results revealed no differences between IGD and control groups when comparing N170 for sad and happy faces. This study neither confirmed the "decreased happy face advantage" phenomenon nor supported the existence of a processing bias toward negative facial expressions in IGD.

Why, then, do the findings from Fan et al. (2022, 2023) and Peng et al. (2017) differ so substantially? First, Fan et al.' s (2022, 2023) behavioral experiments explored micro-expression processing in IGD, whereas Peng et al. (2017) investigated ordinary facial expression processing. Second, in Fan et al.' s (2022, 2023) experiments, participants processed facial expressions consciously, while Peng et al. (2017) examined unconscious facial expression processing in IGD. Third, and most importantly, the researchers used different types of negative facial expressions: Fan et al. (2022, 2023) used angry faces, while Peng et al. (2017) used sad faces. Research has shown that processing of threatening faces is automatic and prioritized (Schupp et al., 2004). From a cognitive processing perspective, threatening faces have more salient perceptual features (Vuilleumier, 2002), and from an evolutionary perspective, prioritized processing of threatening faces is more adaptive. Anger represents a typical threatening facial expression, whereas sadness does not (Fan et al., 2020; McNally, 2019; Schupp et al., 2004; Vuilleumier, 2002). Consequently, sadness does not exhibit priority compared to happy faces, which have processing advantages, explaining why Peng et al. (2017) did not observe decreased happy face processing advantage.

Although threatening face processing is prioritized and automatic, Fan et al.'

s (2022, 2023) findings reveal that this processing priority for angry faces is stronger and abnormal in individuals with IGD compared to controls. The discrepancies in existing research findings stem from differences in the types of negative faces used for comparison, rather than abnormalities in how individuals with IGD process happy faces. Therefore, future research should focus on processing different types of negative facial expressions in IGD rather than broadly comparing negative versus positive facial expressions, which may fail to yield accurate conclusions.

2.2 Abnormal Processing Bias Toward Negative Emotional Distractors in Executive Control Tasks in IGD

Existing IGD emotion interference research employs experimental methods that present emotional stimuli as distractors in executive control tasks (e.g., go/no-go or Stroop paradigms), focusing primarily on the executive control abilities of individuals with IGD under negative emotional interference (Wu, Zhu, et al., 2020) while paying less attention to the characteristics of the emotional stimuli themselves.

Lee et al. (2015) used an emotional Stroop task to investigate interference effects of angry face stimuli, finding that compared to healthy controls, the IGD group showed stronger activation in the insula but weaker activation in the dorsal anterior cingulate cortex (dACC), dorsolateral prefrontal cortex (DLPFC), and posterior parietal cortex when responding to angry face distractors. Lee et al. (2015) interpreted these results using the working mechanisms of the dorsal and ventral attention systems. Specifically, the dACC plays a crucial role in top-down endogenous processing of salient stimuli by the dorsal attention system (comprising dorsal frontal and dorsal posterior parietal cortices) (Bush et al., 2000; Corbetta & Shulman, 2002; Duggirala et al., 2022; Lee et al., 2015; Weissman & Prado, 2012). The insula serves as the hub of the ventral attention system (comprising temporoparietal and ventral frontal cortices) (Eckert et al., 2009; Menon & Uddin, 2010), and the "salience network"formed by the ACC and anterior insula can separate the most relevant stimuli from internal and external inputs to guide behavior (Menon & Uddin, 2010). However, unlike the dorsal attention system, the ventral attention system is driven by exogenous stimuli (Corbetta et al., 2000; Corbetta & Shulman, 2002), and its overactivation can interfere with dorsal attention system functioning (Corbetta & Shulman, 2002; Weissman & Prado, 2012). Therefore, the dACC and insula activation patterns in IGD individuals during angry face interference suggest weakened endogenous processing of stimuli, preventing effective concentration on target stimuli and making them more susceptible to distraction by exogenous emotional distractors. This interpretation has been corroborated by subsequent auditory emotion interference studies, which found that individuals with IGD exhibited failed response inhibition and that response inhibition and emotional states interacted in the dorsomedial prefrontal cortex (DMPFC) during high-load working memory tasks. Researchers suggested this indicates that when individuals with IGD

must regulate emotions during high-load executive control tasks, the DMPFC enhances goal-directedness when emotional states interfere with cognitive control (Shin et al., 2020). Additionally, event-related potential (ERP) studies found that when emotional stimuli served as distractors rather than targets, the IGD group showed smaller nogo-N2 amplitudes but larger nogo-P3 amplitudes compared to controls (Chen et al., 2022), suggesting that individuals with IGD expend more cognitive resources to complete cognitive control tasks under emotional interference and are more susceptible to distractor influence.

From these findings and interpretations, existing research suggests that in individuals with IGD, overactivation of the ventral attention system during emotional interference disrupts dorsal attention system functioning, leading to unreasonable allocation of attentional resources between distractors and targets and making them more easily distracted. Consequently, individuals with IGD must strengthen goal-directedness of the dorsal attention system to successfully complete experimental tasks. However, this interpretation has limitations. First, it focuses on attention deficits in individuals with IGD rather than on the emotional characteristics of the distractors, making it applicable to any distractor that can divert attention without specifying the uniqueness of emotional distractors. Second, most research emphasizes interference from negative emotional stimuli without adequately comparing different types of emotional interference effects. Even in studies that include positive emotional conditions, researchers tend to focus explanations on task properties and paradigms rather than providing sufficient explanation for the interference mechanisms of different emotional stimulus types.

Therefore, approaching from the perspective of emotional stimulus characteristics may help explain the uniqueness of emotional distractors. Chen et al. (2022) reported behavioral results showing that compared to controls, the IGD group exhibited response bias toward angry distractor emotions in both go and no-go trials, consistent with findings from facial expression processing studies (Fan et al., 2022; Fan et al., 2023). Meanwhile, neuroimaging results revealed that individuals with IGD show abnormal automatic processing tendencies toward negative emotional stimuli, manifested as decreased caudate nucleus activation when facing swear words (Chun et al., 2015). Additionally, individuals with IGD exhibited stronger fusiform gyrus activation than controls when confronted with angry face distractors, indicating greater difficulty ignoring angry face interference (Lee et al., 2015). These findings suggest that compared to neutral and positive emotional interference, individuals with IGD demonstrate abnormal automaticity and bias in processing negative emotional distractors, particularly angry emotional distractors. This makes it more difficult for them to enhance goal-directed attention when facing negative emotional distractors, further increasing the difficulty of allocating attention appropriately between targets and distractors and making them more vulnerable to negative emotional stimulus interference.

3 Difficulties in Negative Emotion Regulation in Individuals with IGD

Numerous studies using the Affective Style Questionnaire (ASQ), Difficulties in Emotion Regulation Scale (DERS), and Emotion Regulation Questionnaire for Children and Adolescents (ERQ-CA) have identified emotion regulation difficulties in individuals with IGD (Lin et al., 2020; Müller & Bonnaire, 2020; Uçur & Dönmez, 2021). Unlike facial processing research, experimental studies on emotion reactivity and regulation in IGD primarily use emotional words and pictures as materials, focusing on processing of negative emotional stimuli while also exploring underlying neural mechanisms.

Zhang et al. (2020) found that compared to recreational game users (RGUs), individuals with IGD showed enhanced bilateral insula and right ventral anterior cingulate cortex (vACC) activation during reappraisal of negative emotional pictures. Regarding the functions of the insula and vACC in emotional processing: first, the insula plays an important role in emotion recognition through interoceptive processing and can also decisively influence subjective emotional experiences through interoception (Terasawa et al., 2021). Thus, stronger bilateral insula activation in individuals with IGD during emotion regulation may indicate stronger negative emotional experiences when facing negative emotional stimuli (Zhang et al., 2019; Zhang et al., 2020). Second, Bush et al. (2000) divided the ACC into a dorsal cognitive division (ACcd) and a rostral-ventral affective division (ACad). The ACad has strong connections with the amygdala, anterior insula, and orbitofrontal cortex, primarily participating in emotional evaluation and regulation, with enhanced activation in this region associated with negative emotions. Therefore, stronger right vACC activation in individuals with IGD during emotion regulation may indicate greater sensitivity to and stronger arousal of negative emotions (Zhang et al., 2020). Under these circumstances, individuals with IGD need to effectively regulate excessively aroused negative emotions to maintain normal emotional states.

However, the ability of individuals with IGD to regulate negative emotions is weaker compared to normal populations, as confirmed by numerous neuroimaging studies. First, compared to controls, individuals with IGD show reduced activation in cognitive control-related brain regions when facing swear words and regulating negative emotions, such as decreased activation in the orbitofrontal cortex and fronto-cingulate-parietal network (Chun et al., 2015; Yip et al., 2018), suggesting that reduced emotion regulation capacity in IGD is associated with impaired cognitive control (Zhang et al., 2023). Second, individuals with IGD show enhanced functional connectivity between the right insula and DLPFC during cognitive reappraisal of negative stimuli (Zhang et al., 2020), and research has found that transcranial direct current stimulation (tDCS) applied to the DLPFC can enhance negative emotion regulation ability in individuals with IGD (Wu, Potenza, et al., 2020), indicating that individuals with IGD expend more cognitive resources to regulate negative emotions due to excessive negative emotional arousal. Third, when individuals with IGD experience neg-

ative events during actual gameplay (being attacked by enemies without ability to counterattack), they show weaker activation in the left middle frontal gyrus (MFG) compared to RGUs, and decreased functional connectivity between the left MFG and right amygdala (Zhang et al., 2023). The amygdala is the brain region most closely associated with human emotional processing (Cardinal et al., 2002), playing important roles in emotional perception, regulation, management, and control (Berboth & Morawetz, 2021; Cardinal et al., 2002; Gottfried et al., 2003; Šimić et al., 2021; Tippett et al., 2018). The PFC controls amygdala responses in emotion regulation contexts and has close connections with numerous emotion-related cortical and subcortical structures (Ochsner & Gross, 2005; Phillips et al., 2003; Phan et al., 2005). Dynamic interactions between the amygdala and PFC enable individuals to respond to salient stimuli and regulate emotional reactions to adapt to different situations (Berboth & Morawetz, 2021; Ochsner & Gross, 2005). This suggests that connectivity between the amygdala and PFC plays an important role in emotion regulation (Banks et al., 2007; Ko et al., 2015; Lu et al., 2012). As part of the PFC working network, the MFG also participates in emotion regulation (Zhang et al., 2023). Therefore, decreased functional connectivity between the MFG and amygdala may indicate, at the neural mechanism level, reduced negative emotion regulation capacity in individuals with IGD. Finally, researchers using resting-state fMRI found that female individuals with IGD showed significantly decreased functional connectivity in an anticipated-negative-affective brain network compared to female RGUs, and the strength of this network' s functional connectivity was negatively correlated with maladaptive emotion regulation cognitive strategies, whereas these results were not observed in male individuals with IGD (Wang et al., 2022). This suggests that female individuals with IGD may experience more severe emotion regulation difficulties, making it harder for them to escape negative emotions. In such cases, they are likely to use online gaming as a maladaptive strategy to cope with stressors (Wang et al., 2022), which may also negatively reinforce compulsive gaming craving behaviors.

In summary, the mechanism through which negative emotion regulation difficulties maintain and exacerbate IGD can be explained through the following pathway: individuals with IGD experience excessive emotional arousal when facing negative stimuli. However, due to impaired cognitive control capacity and abnormal functioning in emotion regulation-related brain regions, they encounter difficulties regulating excessively aroused negative emotions, making it harder for them to escape negative emotional states (Ostinelli et al., 2021; Sit et al., 2023). Previous research has found that seeking immediate release from emotional stress and escaping real-world problems constitute part of the motivation for individuals with IGD to engage in online gaming (Lee et al., 2017; Shin et al., 2020), suggesting that online gaming may serve as a maladaptive emotion regulation strategy for individuals with IGD (Gioia et al., 2021; Longstreet et al., 2019). Under this negative reinforcement, individuals with IGD engage in more online gaming, further exacerbating addiction.

4 Theoretical Background of Emotion Regulation in IGD

The mechanism of emotion regulation in IGD has gradually become clarified with the continuous development of theoretical models in this field. In their 2014 theoretical model of internet addiction, Brand and colleagues proposed that IGD represents specific internet addiction (SIA) (hereinafter referred to specifically as IGD). In this model, specific predispositions in individuals enhance the reinforcement they receive from online gaming, leading them to develop expectations that online gaming can effectively alleviate or avoid negative emotions (Brand et al., 2014). Moreover, individuals with IGD are more sensitive to rewards and less sensitive to losses, tend to seek immediate gratification, and exhibit impaired executive control functions (Dong & Potenza, 2014). Based on this, individuals with IGD may amplify the emotional reinforcement experiences derived from online gaming and tend to choose gaming to obtain immediate gratification, yet they struggle to control excessive gaming behavior, which further exacerbates addiction.

Subsequently, Brand et al. (2016) revised and refined the SIA process from their earlier model, proposing the Interaction of Person-Affect-Cognition-Execution (I-PACE) model. In this model, individuals' affective and cognitive responses to internal and external stimuli mediate the relationship between predisposing factors (such as neurobiological and psychological characteristics) and IGD, with conditioning processes potentially strengthening this mediation. Brand et al. (2016) proposed that both internal (e.g., negative emotional experiences) and external stimuli may become conditioned during the addiction process, leading individuals to associate these stimuli with reinforcement experiences from online gaming. Under such conditions, individuals develop expectations that engaging in online gaming can effectively relieve negative emotions when experienced. Furthermore, predisposing factors in addicted individuals (such as being prone to stress and having dysfunctional coping mechanisms) make them more likely to adopt impulsive emotion regulation strategies when facing stress, and combined with their expectations that online gaming can effectively alleviate negative emotions, this makes them more inclined to adopt this dysfunctional emotion regulation approach.

Additionally, Brand et al. (2016) suggested that impulsive emotion regulation may not only influence individuals' decisions about whether to engage in online gaming during the early stages of addiction but may also play a more important role in later addiction development. In their 2019 updated I-PACE model, Brand et al. proposed that in later stages of addiction, the connections between internal or external triggers of affective and cognitive responses and the reinforcement experiences from online gaming become increasingly strong, as do expectations about gaming. Eventually, automated responses to gaming cues and gaming cravings evolve from the affective and cognitive response processes and automatically emerge when facing internal or external triggers. This demonstrates that the mechanisms of emotion regulation differ between early and later stages of addiction, a distinction also reflected in Brand' s (2022) neurocircuitry

model of addiction. This model posits that IGD involves two driving pathways: a "feel better" pathway and a "must do" pathway. The "feel better" pathway, involving emotion and reward processing, is central in the early stages of addiction, while the "must do" pathway plays a greater role in later stages.

In summary, the mechanisms of emotion regulation in IGD have been continuously refined and improved, with theoretical model developments in this area highlighting the important role of emotion regulation in the formation and development of IGD. Later theoretical models reveal that maladaptive emotion regulation may play a more direct role in promoting IGD development in its early stages. Therefore, early interventions and treatments could place greater emphasis on training emotion regulation abilities in individuals with IGD to prevent further addiction progression.

5 Summary and Outlook

In conclusion, numerous behavioral and neuroimaging studies have corroborated that individuals with IGD exhibit abnormalities in negative emotion processing, and the role of emotion regulation in IGD has been continuously refined through theoretical model development. Connecting different aspects of emotional processing abnormalities in IGD may further enrich and develop our understanding of the mechanisms through which emotional processing operates in IGD. Specifically, individuals with IGD show abnormal processing biases toward negative emotional stimuli and exhibit greater neural sensitivity to such stimuli. Simultaneously, individuals with IGD experience stronger emotional arousal when facing negative emotional stimuli, necessitating effective emotion regulation to maintain normal emotional states. However, individuals with IGD struggle to regulate negative emotions effectively and tend to adopt online gaming as a maladaptive emotion regulation strategy. The negative reinforcement produced through this process may further exacerbate addiction, creating a vicious cycle. Therefore, further exploration of emotional processing characteristics in IGD and clarification of their mechanisms in addiction onset, maintenance, and development will facilitate more effective interventions and treatments for IGD.

Based on this understanding, future research could focus on the following aspects:

First, **participant gender ratios and emotional states**. Many studies on emotional processing in IGD have unreasonable gender ratios, with numerous studies excluding female participants (Chun et al., 2015; He et al., 2019; Lee et al., 2018; Shin et al., 2020; Tian et al., 2014; Yip et al., 2018). Since emotion cognition shows gender differences (Montagne et al., 2005; Wells et al., 2016), such participant composition reduces the reliability of research findings. Future studies could determine appropriate gender ratios based on large-sample IGD prevalence research. Additionally, many studies have found that individuals with IGD often experience more severe anxiety and depression than typical participants (Ostinelli et al., 2021; Sit et al., 2023), and emotional states influence

emotional stimulus processing (Fan et al., 2022; Gray et al., 2002). This suggests that researchers should pay greater attention to participants' long-term and short-term emotional states during assessment (Diaz et al., 2016) to better clarify the relationship between IGD and emotional processing abnormalities.

Second, **investigating different aspects of emotional processing in IGD through diverse emotional stimulus designs**. Most existing research has broadly examined negative emotion processing or processing of a single negative emotion type without specifying differences in how individuals with IGD process different types of negative emotions. Moreover, emotion interference research has been limited to angry faces, without in-depth investigation of interference effects from other facial expressions or adequate comparison of interference characteristics across different emotional stimulus types, preventing clear identification of the uniqueness of emotional distractors. Future research could focus more on comparing similarities and differences in processing various types of negative emotions in IGD. Additionally, most studies have used facial expressions depicting basic emotions (e.g., anger and happiness), yet emotions expressed through facial expressions in real life are rarely basic emotions (Halberstadt, 2003), potentially reducing experimental external validity and limiting accurate inference about how facial expression processing abnormalities affect social functioning or contribute to addiction formation and development. Therefore, future researchers could pay greater attention to processing of compound emotional facial expressions in IGD within specific cultural contexts. Furthermore, current studies use static facial expression stimuli, whereas future research could examine processing of dynamic facial expressions in IGD or systematically manipulate emotional intensity to investigate processing of emotions with different arousal levels, thereby further clarifying characteristics of emotional processing in IGD. Finally, beyond presenting pictures, words, and other common emotional stimuli and facial expressions, researchers could present body expressions and vocal tone expressions, as language and gestures also convey emotions (de Gelder & Solanas, 2021; Shin et al., 2020), and processing of these emotional cues also plays important roles in daily interpersonal communication and social interaction. Overall, research on emotional processing in IGD can employ diverse experimental materials combined with appropriate experimental designs to achieve different research purposes and continuously deepen understanding of emotional processing in IGD from multiple perspectives.

Third, **presentation of emotional stimuli**. The vast majority of existing studies present visual emotional stimuli, with only Shin et al. (2020) presenting auditory emotional distractors, indicating limitations in stimulus presentation modalities. Future research could further explore processing of auditory and other forms of emotional stimuli or multi-sensory integration of emotional stimuli (Li et al., 2019), which could also make experimental scenarios more realistic and enhance external validity.

Fourth, **temporal dynamics of emotional processing in IGD**. Based on existing findings, we can confirm that emotional processing is abnormal in indi-

viduals with IGD, but it remains uncertain which specific processing stages are affected. Future research could utilize ERP technology, capitalizing on its high temporal resolution combined with appropriate experimental designs (Wang et al., 2014), to explore whether and what abnormalities exist at various stages of emotional processing in IGD, thereby further clarifying emotional processing mechanisms along the temporal dimension.

Fifth, **group emotional processing in IGD**. Humans are social animals, and when a person identifies with a group, that group becomes an ingroup for that individual. Categorization into ingroups and outgroups leads individuals to evaluate group-related matters with different emotional coloring (Enock et al., 2021; Smith, 1993). However, individuals with IGD exhibit impaired social functioning (Mihara & Higuchi, 2017), and some studies suggest this may be related to difficulties in recognizing facial expressions (Fan et al., 2022; Fan et al., 2023). Therefore, investigating group emotional processing, particularly processing of group facial expressions, in individuals with IGD could further clarify the relationship between IGD and social functioning impairment. Specific methods could include using functional near-infrared spectroscopy (fNIRS) to study interbrain neural synchronization during multi-person social interactions. fNIRS has already been applied in research on face-to-face verbal communication, group decision-making under uncertain others' intentions, and teaching interactions (Nozawa et al., 2016; Quaresima & Ferrari, 2016; Zhao et al., 2023), as well as in dual social interaction tasks with individuals with alcohol use disorder (Guo et al., 2023). Therefore, future research could also use fNIRS to explore neural activity during multi-person social interactions when individuals with IGD process group emotions, thereby further clarifying the neural mechanisms underlying their social functioning impairment.

Sixth, **exploring effective methods to enhance emotion regulation abilities in individuals with IGD**. Individuals with IGD inherently exhibit negative emotion regulation difficulties, and theoretically, maladaptive emotion regulation also plays an important role in IGD formation and development. Therefore, enhancing emotion regulation capacity should be prioritized in IGD interventions and treatments. Research has found that emotion regulation training can effectively improve emotion regulation strategies and promote mental health in addicted individuals (Sabz et al., 2021). Current methods used in emotion regulation training research for addicted individuals include cognitive reappraisal and mindfulness meditation (Sabz et al., 2021; Tang et al., 2016). Given the variety of existing emotion regulation training methods and the scarcity of research on emotion regulation training specifically for IGD, future studies could select more representative methods from similar categories based on the structural relationships among general emotion regulation strategies (Naragon-Gainey et al., 2017).

Seventh, **focusing on emotional processing issues in adolescents with IGD**. According to prevalence research, the IGD population primarily consists of adolescents and young adults (Gao et al., 2022), yet current research on

emotional processing in IGD focuses more on young adults than adolescents. However, the harm of IGD to adolescents' academic performance, parent-child relationships, and physical and mental health cannot be underestimated (Wartberg et al., 2017; Wartberg et al., 2019). The I-PACE model also indicates that emotion regulation may have a more direct impact on early-stage IGD (Brand et al., 2019), suggesting that intervening in emotion regulation for adolescents with IGD may be more effective temporally. This also suggests that future researchers could pay more attention to emotional processing issues in adolescents with IGD to provide more adequate scientific evidence for clinical treatment and intervention.

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