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Original Article

Assessment of Attentional Bias in Internet Gaming Disorder Using the Addiction Stroop Task and Event-Related Potentials

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Abstract

Background: Internet Gaming Disorder (IGD) is defined by a loss of control over gaming habits, prioritizing gaming above daily responsibilities, and persistent engagement despite detrimental outcomes. As a rising public health challenge, IGD significantly disrupts individuals' lives. Investigating attentional biases in IGD is vital for designing targeted interventions.

Methods: Attentional bias was measured in individuals with IGD using the Addiction Stroop Task. The participants were classified into three cohorts: IGD, Recreational Game Users, and non-gaming controls. Electroencephalography/event-related potential (EEG/ERP) data were collected and analyzed from electrodes Pz, Cz, and CPz.

Findings: Compared to the RGU and control groups, the IGD group displayed significantly greater P300 amplitudes and prolonged response latencies to both gaming-related and neutral stimuli. Furthermore, the IGD group reported elevated impulsivity, anxiety, and depression levels relative to the other groups.

Conclusion: Contrary to conventional attentional bias models in addiction—which emphasize preferential attention to addiction-related cues—individuals with IGD exhibited intensified neural reactivity to all stimuli. This suggests excessive cognitive resource mobilization, potentially indicative of hyperarousal or dysregulated neurobiological processes.

Keywords: ERP, Attentional bias, Addiction stroop task, Internet gaming disorder, Recreational game users

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Introduction

Internet Gaming Disorder (IGD) is characterized by persistent and excessive engagement in online gaming, resulting in significant functional impairment, or psychological distress. The American Psychiatric Association (APA) included IGD in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) as a provisional condition warranting further investigation.[1] The World Health Organization (WHO) formally designated Gaming Disorder as a diagnosable condition in the 11th edition of the *International Classification of Diseases* (ICD-11), marking its global acknowledgment as a clinically significant behavioral pattern.[2,3]

The DSM-5 outlines diagnostic criteria for Internet Gaming Disorder (IGD), including obsessive focus on gaming, withdrawal symptoms upon cessation, unsuccessful efforts to reduce gaming time, disinterest in non-gaming activities, persistent gaming despite adverse psychosocial effects, deception about gaming habits, gaming as a coping mechanism for negative emotions, and compromised relationships, education, or career due to gaming.[1] Similar ICD-11 criteria are used for IGD. These include decreased ability to manage one's gaming, prioritizing gaming over other hobbies and everyday activities, and continuing or increasing gaming even after negative effects have occurred.[2,3]

IGD is classified as a non-substance addiction due to its behavioral nature, lacking chemical dependency.[4-9] Neurobiological overlaps between IGD, substance use disorders, and gambling disorders further support this categorization.[10-14] Contributing risk factors include

psychiatric conditions (e.g., ADHD, OCD, and mood disorders), psychosocial vulnerabilities (e.g., interpersonal difficulties, family conflict, and low self-esteem), and maladaptive behaviors such as aggression or suicidal tendencies.[15]

The prevalence of IGD varies depending on the population studied and the criteria used to define the disorder. A meta-analysis of studies on IGD prevalence among adolescents found a pooled prevalence of 4.6%, with male adolescents reporting a higher prevalence rate of 6.8% compared to female adolescents at 1.3%.[16] The lack of agreement in the diagnosis of IGD, together with variations in the use of tools, diagnostic procedures, and management strategies, has been linked to the variation in prevalence.[17]

Examining gaming behaviors across varying intensities such as IGD and Recreational Game Users[18] is critical. Evaluating recreational gaming may benefit from parallels to non-problematic substance use or gambling. Notably, individuals with addiction often exhibit distinct traits compared to non-problematic users. For example, recreational cocaine users demonstrate reduced impulsivity (e.g., lesser delay discounting) and divergent neural responses during cognitive tasks compared to dependent users, suggesting behavioral and neurocognitive distinctions.[19] They showed less activation in the anterior cingulate and orbitofrontal cortex than dependent users and control subjects.[20] Research on recreational behaviors, such as cocaine use or gambling, reveals distinct patterns between non-problematic and addicted individuals. For instance, recreational users often display intermediate impulsivity and neural responses compared to dependent users, with subsyndromal gambling linked to psychopathology.[21-24] Similarly, RGU may share traits with both IGD and non-gamers, such as better self-control than IGD but similar gaming motivations as controls, highlighting behavioral and reward-processing distinctions.[25]

Unlike IGD, RGUs often engage in gaming without loss of control, as most gamers avoid addiction despite inherent risks.[26,27] Attentional bias, a key feature of addiction, drives craving and relapse risk across substance and behavioral addictions.[28-30] Studies on drug-related stimuli (e.g., cocaine, alcohol) and behavioral addictions like IGD demonstrate altered attention patterns, such as slower reaction times in IGD, reflecting neurocognitive dysfunction.[31-33] These biases correlate with disrupted brain activity and connectivity, underscoring the need to explore electrophysiological markers like event-related potentials (ERPs).

ERPs, derived from EEG, measure brain responses to stimuli, with the P300 component (a positive peak ~300 ms post-stimulus) reflecting attention allocation and memory updating.[34,35] This study used the Addiction Stroop Task to compare attentional bias in IGD, RGU, and non-gaming controls. We hypothesized that IGD individuals exhibit stronger bias toward gaming cues and larger P300 amplitudes than RGU and controls, offering insights into cognitive mechanisms and comorbid factors (e.g., anxiety and impulsivity) in IGD.

Methods

Participants

The participants were recruited via social media platforms, with 20 individuals assigned to each group: IGD, RGU, and control. All were right-handed males aged 18–35, with no significant age differences across groups. Exclusion criteria were a history of neurological/psychiatric disorders, traumatic brain injury, substance abuse (excluding nicotine), or psychotropic medication use. To minimize nicotine's influence, participants abstained from smoking for three hours prior to the experiment.[36] IGD was identified based on meeting the suggested 9-item IGD diagnosis per DSM-5 criteria[37] and receiving a score of 50 or higher on Young's(VAT) online Internet addiction test(Figure 1).[38,39]

Questionnaires

The IGD9-SF, a concise 9-item tool derived from the full IGD scale, assesses symptoms like preoccupation with gaming, loss of control, and neglect of daily responsibilities.[40] Young's Internet Use Disorder

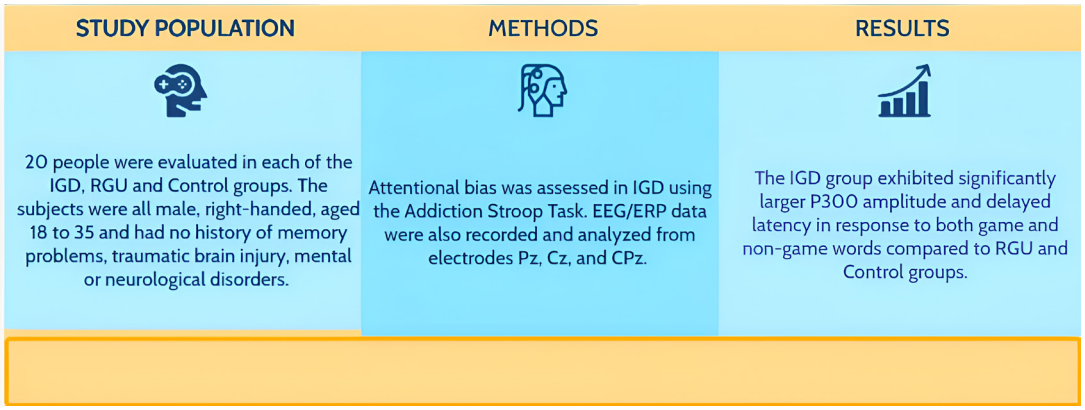

Figure 1. Graphical abstract of the study. IGD: internet gaming disorder, RGU: recreational game user EEG: electroencephalography, ERP: event-related potentials

Assessment (20 items) evaluates problematic behaviors such as withdrawal, psychological dependence, and functional impairments.[38,41]

A range of research supports the use of both IGD and Video Game Addiction Test (VAT) questionnaires in gaming addiction studies. While both IGD9-SF and the VAT are validated in gaming studies,[42,43] critiques highlight limitations in IGD criteria's ability to distinguish between non-problematic gamers and those meeting IGD thresholds.[41] Combining these tools allows the integration of subjective and neurobiological insights into gaming addiction. Four self-reported questionnaires were also given to the participants to complete: the Edinburg Inventory,[44] the Beck Depression Inventory (BDI),[45] the Beck Anxiety Inventory,[46] and the Barratt Impulsiveness Scale 11 (BIS-11).[47]

RGU Group Criteria: Meeting fewer than four DSM-5 IGD criteria, minimal daily life disruption, and an IAT score < 50; consistent two-year gaming history without dependency signs; regular gaming (≥ 5 days/week, ≥ 14 hours/week) without compulsion or regret, maintaining social and occupational commitments.[25]

Experimental Task

The **Addiction Stroop task**, a method widely used to assess attentional bias toward addiction-related cues,[48] was adapted for gaming contexts in this study. The participants viewed 20 gaming-related words (e.g., "Enemy") and 20 neutral control words (e.g., "Energy"), matched for semantic features such as syllable count and word length. To ensure comparable familiarity across groups, preliminary ratings were collected from individuals with and without gaming experience (excluded from the main study), confirming no significant differences in word recognition between terms.

During the task, words were displayed in red, green, or blue using *Times New Roman* font, subtending a visual angle of 2.5.[49] Each word appeared in either congruent (e.g., "red" in red ink) or incongruent colors (e.g., "green" in blue ink). The participants identified the ink color via keyboard presses: left arrow for red, right arrow for blue, and down arrow for green, ignoring semantic content.

Each trial of the Addiction Stroop test lasts 1,500 ms, with 1,250 ms for the ISI and 200 ms for the stimulus (Figure 2). The subject must react to the stimulus in 100-1,000 ms to receive a valid response. There are 360 trials in the Addiction Stroop test, with a 50/50 ratio of congruent to incongruent trials. To determine which key corresponds with which color, participants practiced 63 trials (21 trials for each color) of five X(XXXXX)) colors in succession before taking the Addiction Stroop test. The behavioral factors examined in the Addiction Stroop task include reaction times in congruent and incongruent trials and accuracy rates in responding to congruent and incongruent trials.

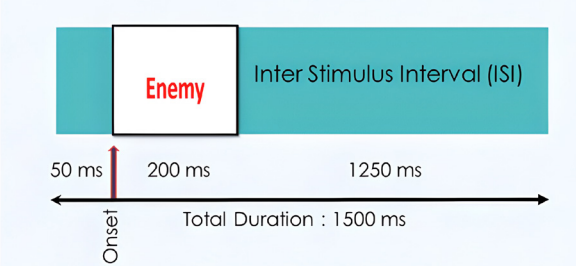

Figure 2. The timeline of the Addiction Stroop task. (Enemy: a game-related word in red print)

ERP Acquisition

EEG data were collected using a 32-channel Win EEG system (Mitsar Inc.), with electrodes positioned according to the 10-20 international system. Two electrooculogram (EOG) electrodes monitored ocular artifacts below the right eye and temporal region. Data were sampled at 500 Hz, with impedances maintained below 5 kΩ and bandpass filtering (0.1–30 Hz). Signals were recorded in a monopolar montage referencing linked earlobes.[36] Artifact correction protocol is divided into three steps: 1. Noise: Manually discard trials with artifacts exceeding 100 μV. 2. Ocular Artifacts: Subtract eye-blink activity via baseline correction. 3. Independent Component Analysis[50]: Isolate and remove muscle/eye-movement artifacts.[51] For the Addiction Stroop task, the P300 component was analyzed within a 250-450 ms post-stimulus window, aligning with established Stroop effect timelines.[52]

Procedure Assessment

During the EEG recording, participants were seated in a dimly lit, sound-attenuated room that complied with ANSI S3.1-1999 standards. Before the completion of the Addiction Stroop task, they completed the mentioned questionnaires. The participants took a comfortable chair, rested in a relaxed posture, and fixed their heads on their chins. A 17-inch monitor screen was placed one meter away from the participants. Psytask version 1.53.17 of the Russian company Mitsar Inc. was used.[36] Every participant signed an informed consent form in writing. EEG is a safe and non-invasive procedure, that causes no harm to participants. The study was approved by the Ethics Committee of Kerman University of Medical Sciences (Ethics Code: IR.KMU.AH.REC.1400.239).

Statistical Analysis

Data normality was assessed using the Kolmogorov-Smirnov test, followed by parametric analyses upon confirmation. Demographic and psychometric variables across IGD, RGU, and control cohorts were analyzed via independent samples *t*-tests. For ERP data, a repeated-measures ANOVA incorporated two within-subjects variables: trial type (gaming-related vs. neutral stimuli) and electrode placement (Pz, Cz, and CPz). Statistical analyses were performed using SPSS v26.

Results

Demographic and Psychometric Outcomes

Tables 1 and 2 display the clinical and demographic traits of the research subjects. The findings indicated that there was no discernible age or educational difference between the three groups. The three groups' scores on the BDI, BAI, and BIS showed substantial variation. Comparing the IGD group to the RGU group, the IGD group spent much more time and days playing online games and had significantly higher scores in VAT and IGD9.

Electrophysiological Data

The analysis of the P300 ERP component in the IGD group revealed significant differences in both amplitude and latency when compared to the RGU and Control groups. The heightened P300 amplitudes and delayed latencies were observed in response to both game and non-game stimuli. Here we examine the results obtained from the amplitude based on the location of the electrodes, word categories, and groups in more detail in Tables 3 and 4 (Amplitude and Latency, respectively).

Table 1. Deogeraphic data of the study participants. The data is presented in Mean ± SD(N/A: not applicable). The statistical significance level is $p < .05$

Variable	IGD	RGU	Control	*P* value
Age(years)	21.3 ± 3.14	20.85 ± 1.93	22.44 ± 2.57	<.43
Education(years)	15.33 ± 3.15	16.03 ± 2.94	16.41 ± 3.21	<.33
IGD9	3.5 ± 0.69	2.42 ± 0.48	N/A	<.001
VAT	3.45 ± 0.42	2.57 ± 0.44	N/A	<.001
Day/Week	6.43 ± 0.51	2.51 ± 1.97	N/A	<.000
Hours/Day	5.83 ± 1.17	1.27 ± 1.08	N/A	<.000

Discussion

This study enhances understanding of Internet Gaming Disorder (IGD) by combining the Addiction Stroop task with event-related potential (ERP) measures, revealing attentional biases in affected individuals. Results demonstrate that the IGD group exhibited significantly greater P300 amplitudes and slower response latencies to both gaming-related and neutral stimuli compared to recreational[18] and non-gaming controls, suggesting widespread deficits in attentional regulation.

Table 2. Psychometric data of the participants. The data is presented in Mean ± SD(N/A: not applicable). The statistical significance level is $p < .05$

Groups	BIS-II (*P* value)	BDI (*P* value)	BAI (*P* value)
Contol VS IGD	<.000	<.000	<.038
Control VS RGU	<.006	<.34	<.82
IGD VS RGU	<.064	<.000	<.022

Table 3. Comparison of P300 ERP wave amplitude in IGD, RGU and Control groups in 3 electrodes Pz, Cz and CPz. RNG(Red Non-Game related word), BNG(Blue Non-Game related word), GNG(Green Non-Game related word), RG(Red Game related word), BG(Blue Game related word), GG(Green Game related word). The data is presented as a *p*-value. The statistical significance level is $p < .05$

Groups	Electrodes	RG (*P* value)	BG (*P* value)	GG (*P* value)	RNG (*P* value)	BNG (*P* value)	GNG (*P* value)
	Pz	<.21	<.71	<.005	<.001	<.002	<.001
Control VS RGU	Cz	<.092	<.09	<.26	<.82	<.05	<.02
	CPz	<.001	<.22	<.002	<.73	<.97	<.82
	Pz	<.001	<.001	<.001	<.001	<.008	<.001
Control VS IGD	Cz	<.005	<.001	<.001	<.011	<.001	<.85
	CPz	<.17	<.001	<.001	<.001	<.27	<.008
	Pz	<.03	<.001	<.001	<.051	<.86	<.79
RGU VS IGD	Cz	<.001	<.06	<.001	<.051	<.41	<.07
	CPz	<.001	<.001	<.001	<.001	<.19	<.03

Table 4. Comparison of P300 ERP wave latency in IGD, RGU and Control groups in 3 electrodes Pz, Cz and CPz. RNG(Red Non-Game related word), BNG(Blue Non-Game related word), GNG(Green Non-Game related word), RG(Red Game related word), BG(Blue Game related word), GG(Green Game related word). The data is presented as a *p*-value. The statistical significance level is $p < .05$

Groups	Electrodes	RG (*P* value)	BG (*P* value)	GG (*P* value)	RNG (*P* value)	BNG (*P* value)	GNG (*P* value)
	Pz	<.001	<.495	<.002	<.001	<.18	<.068
Control VS RGU	Cz	<.039	<.344	<.021	<.001	<.001	<.342
	CPz	<.003	<.001	<.001	<.001	<.001	<.722
	Pz	<.001	<.001	<.001	<.001	<.001	<.001
Control VS IGD	Cz	<.001	<.001	<.001	<.001	<.001	<.001
	CPz	<.001	<.001	<.001	<.001	<.001	<.001
	Pz	<.001	<.001	<.001	<.001	<.001	<.001
RGU VS IGD	Cz	<.001	<.001	<.001	<.001	<.001	<.001
	CPz	<.001	<.001	<.001	<.001	<.001	<.001

The heightened P300 amplitude aligns with prior research linking elevated responses to emotionally salient cues, such as gaming-related stimuli in IGD.[52] Delayed latencies further indicate impaired disengagement from such cues, consistent with neural mechanisms implicated in IGD pathology.[53] Notably, a Chinese study found that individuals with gaming addiction showed larger P300 amplitudes for gaming cues versus neutral words, while casual gamers displayed no such distinction.[54] Elevated impulsivity, anxiety, and depression in the IGD group corroborate established associations between these traits and gaming disorder.[55]

In explaining why, contrary to previous studies, IGD in addition to game-related stimuli, showed significantly larger P300 amplitudes and delayed latencies in response to non-game-related stimuli, two possibilities can be suggested: hyperarousal and change of neurobiological mechanisms: The unexpected P300 responses to *non-gaming* stimuli in IGD may reflect two mechanisms: hyperarousal and neurobiological alterations**.** Hyperarousal, common in addictive disorders, is linked to excessive attentional resource allocation toward salient cues.[56-58] This state may extend to neutral stimuli in IGD, explaining the observed neural hyperactivity.

Attentional bias and P300 ERP play crucial roles in addiction research. Studies on abstinent heroin addicts (AHAs) displayed hypersensitivity to reward-related stimuli, showing weaker attentional control compared to healthy controls.[59] Research on behavioral addictions reveals distinct neurocognitive patterns. For instance, individuals with elevated Internet Addiction Test scores demonstrate reduced feedback-related negativity (FRN)**,** a negative ERP component peaking 200–300 ms post-feedback and linked to prediction error signaling.[59-61] alongside heightened P300 amplitudes, suggesting amplified reward sensitivity and attentional bias toward addiction-related cues.[62] Similarly, heroin-dependent individuals exhibit altered ERP components (e.g., P100, P200, N200, P300) during drug-related cue processing, reflecting dysregulated attention allocation.[63] These patterns underscore the role of P300 as a neural marker of attentional bias across substance and behavioral addictions, including IGD. The Addiction Stroop task is a valuable tool in addiction research for measuring attentional bias toward substance-related stimuli. Studies have shown that individuals with various addictions, such as methamphetamine (MA) abusers with or without psychosis, participants with internet addiction disorder, and abstinent smokers prone to relapse, exhibit distinct patterns in ERPs during the addiction Stroop task. These ERP changes include alterations in components like N200, P300, N450, and late positive potential, reflecting differences in cognitive processing and cue reactivity.[52, 64, 65]

Future research should aim to replicate these results in larger, more diverse populations. Additionally, longitudinal studies are needed to determine the causality and directionality of the relationship between attentional bias and IGD. By focusing on the cognitive and emotional aspects of IGD, we can move toward more effective intervention strategies that not only treat the symptoms but also address the root causes of the disorder.

Conclusion

In contrast to the traditional definition of attentional bias, which usually involves a preference for addiction-related cues, the IGD group exhibited significantly larger P300 amplitude and more delayed latency towards both game and non-game cues in comparison to RGU and Control groups. These findings imply that individuals with IGD may direct heightened attentional capacity toward processing both gaming-related and neutral cues. Such amplified neural activity could reflect hyperarousal states or dysregulated neurobiological processes characteristic of the disorder.

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Writing–original draft: Sina Motamedy.
Writing–review & editing: Sina Motamedy.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Data Availability statement

The datasets generated during this study are available upon reasonable request from the corresponding author.

Ethical Approval

The study was approved by the Ethics Committee of Kerman University of Medical Sciences (Ethics Code: IR.KMU.AH.REC.1400.239).

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