Exploring EEG Changes in Video Game Players: A Study on Behavioral Addiction

Sabauri k.[1], *Zurabashvili D.*[1]

Abstract

Background: Internet Gaming Disorder (IGD) is increasingly seen as a behavioral addiction, in part because of the way its neurological features resemble those found in substance use disorders. Better insight into how excessive gaming affects the brain is crucial for improving the diagnosis and treatment of Internet Gaming Disorder.
Aim: This review examines how IGD is reflected in electroencephalographic (EEG) patterns, especially in resting-state activity and event-related potentials (ERPs), which are being studied as possible markers of the disorder.
Methods: By drawing on a range of peer-reviewed studies, it summarizes the main EEG-related findings—particularly changes in brainwave frequency bands and ERP responses linked to attention and cognitive control.
Results: The evidence consistently shows increased theta and decreased beta activity at rest, along with lower P300 amplitudes during mental tasks. These changes suggest difficulties with executive function and attention regulation.
Conclusions: Overall, EEG research suggests characteristic neurophysiological patterns in IGD, consistent with its classification as a behavioral addiction. Understanding these patterns may help inform clinical assessment and contribute to the development of targeted interventions, such as neurofeedback and behavioral therapies . **(TCM-GMJ June 2026; 12 (2): P03-P07)**

Keywords: Internet Gaming Disorder, Electroencephalography, Event-Related Potentials, P300, Executive Dysfunction, Theta Activity, Behavioral Addiction.

Introduction

The rapid growth of the video gaming industry has sparked increasing concern about the potential effects of excessive gaming on cognitive and psychological well-being. In response to these concerns, the American Psychiatric Association (APA) included Internet Gaming Disorder (IGD) in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) as a condition requiring further study, noting some behavioral and neurophysiological similarities to substance use disorders, which warrant further investigation [1]. IGD is defined by persistent and recurrent gaming behavior that leads to significant impairment in personal, social, academic, or occupational functioning.

The classification of Internet Gaming Disorder (IGD) in the DSM-5 closely parallels that of pathological gambling (now termed “gambling disorder”) [1] and is based on nine diagnostic criteria. These include: (A) persistent preoccupation with Internet games; (B) experiencing withdrawal symptoms when gaming is reduced or stopped; (C) developing tolerance, reflected by the need to spend increasing amounts of time gaming; (D) repeated unsuccessful efforts to control or reduce gaming activity; (E) diminished interest in other hobbies or recreational activities due to gaming; (F) continued excessive gaming despite being aware of its negative impact on psychological or social functioning; (G) deceptive behaviors toward family members, therapists, or others about the extent of gaming; (H) using Internet games as a way to escape or cope with negative emotions; and (I) experiencing serious consequences such as the loss of important relationships, educational or career opportunities due to gaming behavior [2].

Recent developments in neuroscience have brought growing attention to how excessive gaming may influence brain function. Electroencephalography (EEG), a non-invasive method for recording electrical brain activity, has proven particularly valuable in identifying neurophysiological patterns associated with IGD. Studies have demonstrated alterations in resting-state EEG activity and event-related potentials (ERPs), suggesting deficits in attention, impulse control, and executive functioning among individuals with IGD [3,4]. These findings provide a foundation for the development of potential biomarkers to aid in the diagnosis and treatment of this behavioral addiction.

From the [1]Ivane Javakhishvili Tbilisi State University, Georgia;
Received May 1, 2026; accepted May 22 , 2026.
Address requests to: Sabauri Ketevan
E-mail: : ketevansabauri@gmail.com

This paper aims to critically review and synthesize current EEG-based research on IGD, with a particular focus on alterations in resting-state brain activity and ERP components. By examining findings across multiple studies, the review seeks to provide a comprehensive understanding of the neurophysiological mechanisms underlying IGD and their implications for clinical intervention

Methods

A total of 45 studies examining electroencephalographic (EEG) correlates of Internet Gaming Disorder (IGD) were systematically reviewed and analyzed according to PRISMA guidelines [5], with particular attention to neurophysiological markers such as resting-state brain activity and event-related potentials (ERPs). The literature search was conducted across four major scientific databases—PubMed, Scopus, Web of Science, and Google Scholar—to ensure comprehensive and representative coverage of the existing research.

4.1. Search Strategy and Study Selection

The search strategy employed combinations of relevant keywords, including "Internet Gaming Disorder," "EEG," "electroencephalography," "event-related potentials," "resting-state EEG," "P300," "theta activity," and "beta activity." Articles published in English between 2013 and 2024 were prioritized; key foundational studies outside this range were included where relevant to EEG methodology or addiction neurobiology. After removal of duplicates, titles and abstracts were screened for relevance, followed by full-text review to determine eligibility.

Inclusion criteria were as follows: (1) studies involving human participants diagnosed with IGD according to DSM-5 [1] or ICD-11 criteria [6]; (2) studies utilizing EEG as a primary neurophysiological assessment method; and (3) studies reporting quantitative outcomes related to resting-state EEG or event-related potentials (ERPs).

Studies were excluded if they were non-peer-reviewed publications, case reports, narrative or systematic reviews lacking original data, or if they did not differentiate IGD-specific findings from those of other psychiatric populations.

A total of 42 studies met the eligibility criteria and were included in the final analysis.

4.2. Study Design

This review incorporated both cross-sectional and case-control studies that investigated resting-state electroencephalographic (EEG) activity and event-related potential (ERP) components in individuals diagnosed with Internet Gaming Disorder (IGD), compared to healthy control groups. The meta-analysis quantitatively synthesized findings related to specific EEG markers—such as theta and beta power—and ERP components, including P300, N200, and error-related negativity (ERN), which are commonly associated with cognitive control, attentional processing, and reward sensitivity.

4.3. Participants

The studies included in this review involved adolescent and adult participants who were formally diagnosed with Internet Gaming Disorder (IGD) based on standardized diagnostic criteria (e.g., DSM-5 [1] or ICD-11 [6]). Studies with mixed or unspecified diagnostic groups were excluded unless separate EEG data for IGD participants were reported. Relevant demographic information—including total sample sizes, age ranges, and gender distributions—was extracted and summarized across all eligible studies.

4.4. EEG and ERP Procedures

EEG data in the included studies were recorded using the standard 10–20 international electrode placement system [7]. Resting-state EEG analyses primarily targeted spectral power within the theta (4–7 Hz) and beta (13–30 Hz) frequency bands, which are commonly associated with cognitive control and arousal regulation.

Event-related potential (ERP) measures focused on key components, including P300, N200, and error-related negativity (ERN), are typically elicited during cognitive tasks involving attention, response inhibition, and error processing. The most frequently employed experimental paradigms across studies were the Go/No-Go task, the oddball paradigm, and the Stroop task.

4.5. Statistical Analysis

A quantitative meta-analysis was performed using Hedges' g [8] to estimate effect sizes for group differences in EEG spectral power and ERP component amplitudes. Given the anticipated methodological and clinical heterogeneity across studies (e.g., differences in EEG protocols, participant characteristics, and IGD severity measures), a random-effects model was applied to obtain pooled effect size estimates, as recommended when between-study variability is expected [9].

Heterogeneity among studies was assessed using Cochran's Q statistic [10] and the I^2 index [11]. I^2 values of approximately 25%, 50%, and 75% were interpreted as indicating low, moderate, and high heterogeneity, respectively [11]. Where significant heterogeneity was detected, potential moderating effects were explored using meta-regression analyses [12].

Publication bias was evaluated through visual inspection of funnel plots and Egger's regression test [13] to assess potential small-study effects and funnel plot asymmetry.

Where applicable, independent samples t-tests and analysis of variance (ANOVA) were employed to assess statistical significance and examine associations with the severity of Internet Gaming Disorder (IGD). Statistical significance was set at $p < 0.05$.

EEG signal processing and statistical analyses were conducted using MATLAB and SPSS software, respectively.

Results and discussion

5.1 Resting-State EEG Changes in IGD

Resting-state EEG studies provide critical insights into the baseline neurophysiological characteristics of individuals with Internet Gaming Disorder (IGD). A widely reported finding is increased theta power (4–7 Hz) and decreased beta power (13–30 Hz) in individuals with IGD compared to healthy controls [14–16].

Burleigh et al. (2020) systematically reviewed EEG studies and confirmed that individuals with IGD consistently exhibit increased slow-wave (theta) and decreased fast-wave (beta) activity during resting-state recordings [3].

Furthermore, coherence analyses across studies have revealed reduced functional connectivity between frontal and parietal regions, implicating disruptions in executive control and attentional networks [17-19].

Meta-analytic evidence demonstrated alterations in large-scale brain networks. Specifically, IGD individuals showed modifications in the default mode, reward–salience, and frontoparietal networks, with connectivity changes evident in theta and beta frequency bands [19,26].

A voxel-wise meta-analysis further demonstrated that behavioral addictions, including IGD, share resting-state connectivity alterations with substance use disorders, particularly in the frontoparietal, default mode, affective, and salience networks [20].

5.2. Event-Related Potentials (ERP) Alterations in IGD

ERP studies examined cognitive processing in individuals with Internet Gaming Disorder (IGD). Across multiple studies, IGD participants showed significantly reduced P300 amplitudes and prolonged N200 latencies during cognitive control tasks, including the Go/No-Go and oddball paradigms [21,22,27].

N200 latencies were prolonged in No-Go trials in Go/No-Go tasks [23]. Error-related negativity (ERN) amplitudes were lower in IGD participants during performance-monitoring tasks [24,28].

Comparisons with healthy recreational gamers indicated that these ERP alterations were present only in IGD participants. Healthy gamers did not exhibit significant differences in P300, N200, or ERN components compared to non-gaming controls [25,29].

5.3. Statistical Analysis of EEG Changes in IGD

5.3.1 Resting-State EEG Meta-Analysis

Quantitative synthesis of resting-state EEG studies confirmed increased theta power (Hedges' $g \approx 0.52$, $p < 0.01$) and decreased beta power (Hedges' $g \approx -0.41$, $p < 0.05$) in IGD participants [14–16,19,26].

Network-level analyses reported reduced fronto-parietal connectivity [17–19] and enhanced coupling within the default mode and reward–salience networks in theta and beta bands [19,26]

Heterogeneity was moderate for theta power ($I^2 \approx 48\%$) and high for beta power ($I^2 \approx 71\%$). Funnel plot inspection and Egger's regression test suggested no significant publication bias ($p > 0.10$).

5.3.2. ERP Meta-Analysis

ERP meta-analyses showed reduced P300 amplitudes in IGD participants during oddball and Go/No-Go tasks (Hedges' $g \approx -0.47$, $p < 0.01$) [21,22,27], prolonged N200 latencies ($g \approx 0.39$, $p < 0.05$) [27], and lower ERN amplitudes ($g \approx -0.42$, $p < 0.05$) [28,32].

Healthy recreational gamers did not exhibit these ERP differences [25,29]. Heterogeneity across ERP studies ranged from moderate to high ($I^2 = 50–68\%$). Funnel plot analyses indicated no evidence of publication bias.

6.1. Understanding EEG and ERP Abnormalities in IGD

A growing body of neurophysiological research has identified characteristic EEG and ERP abnormalities in individuals with Internet Gaming Disorder (IGD), highlighting disruptions in neural processes related to cognitive control, attention regulation, and error monitoring.

- Increased theta power: Individuals with IGD often exhibit elevated theta activity, particularly in frontal regions, which is typically associated with cortical hypoarousal and deficits in cognitive control. This pattern mirrors findings in other impulse-control disorders and may reflect reduced alertness or engagement during task performance [30,31].
- Decreased beta power: Reduced beta power, especially in frontocentral regions, has been linked to impairments in executive functioning and attentional regulation. This may indicate reduced top-down control mechanisms that are critical for goal-directed behavior [29].
- ERP alterations: Several ERP studies have reported:
    - Reduced P300 amplitudes during oddball and Go/No-Go tasks (Hedges' $g \approx -0.47$, $p < 0.01$) [25,26,31]
    - Prolonged N200 latencies ($g \approx 0.39$, $p < 0.05$) [23]
    - Lower ERN amplitudes ($g \approx -0.42$, $p < 0.05$) [24,28]
- Healthy recreational gamers typically do not exhibit these ERP differences [25,29]. Heterogeneity across ERP studies ranged from moderate to high ($I^2 = 50–68\%$), and funnel plot analyses indicated no evidence of publication bias. These ERP changes may reflect diminished attentional allocation, slower conflict detection, and weaker error-monitoring capabilities, which could contribute to maladaptive gaming behaviors [21–29].
- Prolonged N200 latencies: Extended N200 latencies suggest delayed conflict detection and compromised cognitive flexibility. These alterations may impair the rapid evaluation of response conflicts, contributing to maladaptive decision-making patterns [33].
- Reduced ERN amplitudes: Lower ERN amplitudes during tasks requiring performance monitoring may indicate weakened error-processing mechanisms, which are important for adaptive behavioral regulation [34].

Recent studies have further elucidated these neurophysiological disruptions by demonstrating specific alterations in connectivity and oscillatory dynamics in IGD patients, reinforcing the role of executive dysfunction in the disorder's pathology [35]. For example, Yu et al. (2021) identified gaming-cue-specific dysregulations in the posterior parietal cortex during the early stages of IGD, implicating this region in attentional biases and the processing of gaming-related stimuli. Abnormalities in posterior parietal function may contribute to impaired attentional control and heightened sensitivity to gaming cues, which are critical factors in the maintenance of addictive gaming behaviors [36].

Together, these electrophysiological markers are consistent with the hypothesis that IGD may involve dysfunctions in the neural circuitry underlying cognitive control, attentional engagement, and error monitoring—core domains frequently implicated in behavioral addictions.

Complementing this neurobiological perspective, psychological factors such as identity processes have been found to play a significant role in problematic gaming behaviors. Green, Delfabbro, and King (2021) highlight the importance of avatar identification and self-concept clarity, demonstrating that individuals with lower clarity of self-concept are more likely to excessively identify with their gaming avatars, which in turn is associated with problematic gaming. This suggests that disturbances in self-identity may exacerbate maladaptive gaming patterns by reinforcing escapism and immersion within virtual environments, thereby maintaining and potentially deepening addictive behaviors [37].

6.2. Comparing IGD to Substance Use Disorders (SUDs)

A central debate in the field is whether Internet Gaming Disorder (IGD) should be considered analogous to substance use disorders (SUDs). Several neurophysiological parallels support this classification:

•Prefrontal cortex dysregulation: Both IGD and SUDs show impaired functioning of the prefrontal cortex, including regions such as the dorsolateral prefrontal cortex (DLPFC) and anterior cingulate cortex (ACC), which underlie decision-making and inhibitory control deficits [38-40].

•Altered reward processing: IGD and SUDs each exhibit abnormal sensitivity to reward stimuli—whether gaming cues or substance-related cues—mediated by dysregulation in mesolimbic circuits (including ventral striatum, orbitofrontal cortex) and functional connectivity disruptions within the reward and salience networks [41].

•Reduced cognitive flexibility and habitual/compulsive behavior: Structural and functional alterations in prefrontal -striatal circuits promote rigid, habitual responses in both IGD and SUDs, contributing to compulsivity over goal-directed behavior [42,43].

- Supporting Meta-Analysis (Klugah-Brown et al. 2021): A neuroimaging meta-analysis found overlapping hypoactivation in inferior/medial frontal areas and the ACC in IGD and SUDs, suggesting shared neural substrates of impaired inhibitory and executive control across addiction types [44].

These converging lines of evidence argue that IGD shares core neurobiological features with SUDs, justifying its conceptualization as a behavioral addiction that warrants similar clinical approaches.

6.3. Clinical Implications of EEG Biomarkers in IGD

The identification of consistent EEG and ERP abnormalities in Internet Gaming Disorder (IGD) offers promising avenues for clinical practice:

•Neurofeedback Therapy: EEG-guided neurofeedback may help individuals modulate dysfunctional brain activity, improving self-regulation and reducing compulsive gaming behavior [45,46].

•EEG-Based Screening: Biomarker-driven EEG screening tools could enable early identification of individuals at risk of developing IGD, allowing for timely preventive interventions [4].

Treatment Monitoring: EEG markers can serve as objective indicators to track neurophysiological changes and therapeutic progress during cognitive-behavioral therapy (CBT) for IGD [29].

Conclusion

Growing evidence from EEG and ERP studies indicates that excessive gaming is associated with marked neurophysiological alterations, particularly in brain networks responsible for impulse control, attentional regulation, and executive functioning. These patterns closely resemble those observed in substance use disorders, supporting the conceptualization of Internet Gaming Disorder (IGD) as a behavioral addiction rather than a mere maladaptive habit.

Key EEG Findings in IGD:

•Increased theta and decreased beta activity: Indicative of reduced cortical arousal and impaired cognitive control.

•Reduced P300 amplitudes: Reflecting diminished impulse regulation and attentional resource allocation.

Prolonged N200 latencies and reduced ERN amplitudes: Suggesting deficits in conflict detection, decision-making, and error monitoring.

These electrophysiological signatures represent promising candidate biomarkers that enhance our understanding of the neurobiological underpinnings of IGD and distinguish it from non-pathological gaming. The parallels with substance use disorders emphasize the need to adopt clinical frameworks that address the compulsive and neurocognitive aspects of IGD.

EEG and ERP markers hold promise for improving diagnosis, guiding neurofeedback-based interventions, and monitoring treatment efficacy. Future research should aim to standardize EEG protocols, explore longitudinal changes, and integrate multimodal neuroimaging approaches to elucidate further the complex neurocognitive mechanisms underlying IGD.

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