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Internet Gaming Disorder among Indian Adolescents: Neurobiological Vulnerability, Developmental Risk, and Environmental Modulation within a Bio psychosocial Framework

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Abstract

Internet Gaming Disorder (IGD) has emerged as a major behavioral addiction affecting adolescents worldwide and represents a rapidly growing public mental health concern in India. Accelerated digitalization, widespread smartphone availability, and sociocultural pressures have dramatically increased adolescents' exposure to immersive online gaming environments. Recent Indian studies report prevalence rates of problematic gaming and IGD ranging from 5.3% to 15%, with higher vulnerability observed among males, urban youth, and college-going adolescents (Gurjar et al., 2024).

Although psychosocial correlates such as academic stress, family conflict, peer influence, and emotional dysregulation are well documented, growing neuroscientific evidence suggests that Internet Gaming Disorder is fundamentally rooted in neurobiological vulnerability, particularly during adolescence. Neurodevelopmental immaturity of prefrontal regulatory systems, combined with heightened sensitivity of reward-related neural circuits, creates a developmental window of susceptibility to addictive behaviors (Paulus et al., 2018). Online gaming exploits this vulnerability through rapid, unpredictable, and high-intensity digital rewards that dysregulate dopaminergic and serotonergic neurotransmission (Koepp et al., 1998; Weinstein et al., 2017).

This review critically synthesizes global and Indian literature to examine IGD through a neurobiologically anchored biopsychosocial framework, positioning neurodevelopmental and neurochemical vulnerability as the primary substrate, while conceptualizing environmental and sociocultural factors as modulators influencing onset, severity, and persistence. Drawing on neuroimaging, neurochemical, psychological, and sociocultural studies published between 2015 and 2025, this article integrates empirical findings with Indian contextual realities. The review highlights implications for prevention, clinical intervention, and public health policy and argues for culturally sensitive, developmentally informed strategies to address gaming addiction among Indian adolescents.

Keywords: Internet Gaming Disorder; Adolescence; Dopamine; Serotonin; Neurodevelopment; Parenting; India

1. Introduction

The rapid expansion of digital technology has transformed patterns of leisure, communication, and social interaction across the globe. Online gaming has become one of the most dominant recreational

activities among adolescents, offering immersive virtual environments, social interaction, competition, and immediate gratification. In India, the convergence of affordable smartphones, inexpensive internet data, and aggressive digital marketing has resulted in unprecedented access to online gaming platforms among young people.

India is currently one of the fastest-growing gaming markets worldwide, with adolescents and young adults constituting a substantial proportion of users. While moderate gaming can foster certain cognitive skills and social connections, excessive and uncontrolled gaming has been increasingly associated with adverse outcomes, including sleep disturbance, academic decline, emotional dysregulation, interpersonal conflict, and impaired psychosocial functioning (Paulus et al., 2018).

The clinical significance of problematic gaming has been formally recognized through the inclusion of Gaming Disorder in the International Classification of Diseases, 11th Revision (ICD-11), and the identification of Internet Gaming Disorder as a condition warranting further study in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (American Psychiatric Association, 2013). Indian research indicates prevalence estimates of IGD ranging from 5.3% to 15%, particularly among urban male adolescents and college students (Gurjar et al., 2024). Despite these findings, Indian discourse has largely framed gaming addiction as a behavioral or psychosocial problem, often emphasizing parental control, moral discipline, or academic motivation.

While environmental factors undoubtedly shape gaming behavior, an exclusive psychosocial framing risks obscuring the central role of neurobiological vulnerability. Contemporary addiction neuroscience demonstrates that behavioral addictions share core neurobiological mechanisms with substance-related disorders, including reward dysregulation, impaired inhibitory control, and maladaptive neuroplasticity (Brand et al., 2019). This review argues that Internet Gaming Disorder in adolescents is best understood as a neurodevelopmentally rooted condition, wherein environmental factors modulate but do not replace underlying biological susceptibility.

2. Adolescence as a Critical Neurodevelopmental Period

Adolescence is characterized by profound structural and functional brain maturation. Neurodevelopment during this period is marked by an imbalance between early-maturing subcortical reward systems and the delayed maturation of prefrontal regulatory regions responsible for executive control, impulse inhibition, and long-term planning (Paulus et al., 2018).

Reward-related brain regions, including the ventral striatum and nucleus accumbens, demonstrate heightened reactivity during adolescence, resulting in increased sensitivity to novelty, reward, and peer approval. In contrast, the prefrontal cortex—particularly the dorsolateral and orbitofrontal regions continues to mature well into the mid-to-late twenties. This developmental mismatch increases vulnerability to risk-taking and addictive behaviors, especially when adolescents are exposed to highly reinforcing stimuli such as online gaming (Weinstein et al., 2017).

In the Indian context, this neurodevelopmental susceptibility often intersects with sociocultural stressors. Academic competition, high parental expectations, limited recreational infrastructure, and rapid urbanization may increase emotional strain and reduce opportunities for adaptive coping. Online gaming may thus function as an accessible and socially sanctioned coping mechanism during a period of heightened emotional and neurobiological sensitivity.

3. Neurobiological Vulnerabilities Underlying Internet Gaming Disorder

3.1 Dopaminergic Reward System Dysregulation

Dopamine plays a central role in reward processing, motivation, reinforcement learning, and habit formation. Positron emission tomography studies have demonstrated that video gaming activates the mesolimbic dopamine system, including dopamine release in the ventral striatum, in a magnitude comparable to psychoactive substances (Koepp et al., 1998).

Repeated exposure to gaming-related rewards leads to neuroadaptive changes, including down-regulation of dopamine D2 receptors. This adaptation produces a reward-deficiency state, wherein increasing levels of stimulation are required to achieve the same hedonic response, thereby promoting tolerance and compulsive gaming behavior (Weinstein et al., 2017). Altered dopamine transporter availability has also been observed in individuals with IGD, contributing to prolonged dopaminergic signaling and impaired reward regulation (Liu & Luo, 2015).

Over time, gaming behavior transitions from voluntary, pleasure-driven engagement to habitual and compulsive use. This shift reflects a transition from prefrontal-mediated goal-directed control to striatum-dominated habit circuitry, a hallmark of addiction across behavioral and substance-related disorders (Brand et al., 2019).

3.2 Digital Reward Speed, Intensity, and Variability

The addictive potential of online gaming is amplified by the structural design of digital reward systems. Games operate on variable ratio reinforcement schedules, delivering unpredictable rewards that maximize dopaminergic firing and behavioral repetition (Vondráčková & Gabrhelík, 2016). Unlike real-world rewards, digital rewards are immediate, frequent, and continuously accessible.

For adolescents with underdeveloped inhibitory control, resisting such rapid reward cues is particularly challenging. The absence of natural stopping points and the constant availability of in-game incentives encourage prolonged engagement, contributing to loss of control and behavioral persistence despite negative consequences.

3.3 Serotonergic Dysfunction and Impulsivity

Serotonin plays a critical role in impulse control, emotional regulation, and behavioral inhibition. Reduced serotonergic activity has been linked to impulsivity, mood instability, aggression, and compulsive behaviors among individuals with Internet Gaming Disorder (Wang et al., 2018).

Excessive gaming is frequently associated with sleep deprivation, circadian rhythm disruption, and reduced exposure to natural light, all of which impair serotonin and melatonin regulation. Vitamin D deficiency, common among adolescents with predominantly indoor lifestyles, may further compromise serotonergic functioning. These neurochemical disturbances weaken self-regulatory capacity and perpetuate compulsive gaming behavior (Weinstein et al., 2017).

3.4 Structural and Functional Brain Alterations

Structural magnetic resonance imaging studies have reported reduced gray matter volume in the dorsolateral prefrontal cortex, orbitofrontal cortex, and anterior cingulate cortex among adolescents with IGD (Kühn et al., 2011). These regions are essential for executive control, decision-making, emotional regulation, and error monitoring.

Functional connectivity studies further demonstrate decreased connectivity within cognitive control networks and increased connectivity within reward-related circuits. This imbalance reflects impaired top-down regulation of reward-driven impulses, contributing to continued gaming despite awareness of negative consequences (Weinstein et al., 2017).

3.5 Glutamatergic and Neuroplastic Mechanisms

Emerging evidence suggests that glutamatergic dysregulation contributes to compulsive gaming. Elevated glutamate levels within the striatum may strengthen cue-reward associations and facilitate habit learning, reinforcing gaming-related neural pathways (Weinstein et al., 2017). These neuroplastic changes highlight the chronic and self-reinforcing nature of IGD.

4. Psychosocial and Environmental Modulators of Neurobiological Vulnerability

Although neurobiological vulnerability forms the foundational substrate of Internet Gaming Disorder, psychosocial and environmental factors play a crucial role in shaping how this vulnerability is expressed during adolescence. These factors do not operate as independent causes of addiction; rather, they interact with and modulate underlying neurodevelopmental and neurochemical susceptibilities, influencing the onset, severity, and persistence of disordered gaming behavior (Brand et al., 2019).

4.1 Family Environment and Parenting Practices

The family environment represents one of the most influential psychosocial contexts affecting adolescent gaming behavior. Empirical studies consistently demonstrate that poor parent–child attachment, emotional neglect, inconsistent supervision, and high levels of family conflict are associated with increased risk of Internet Gaming Disorder (Bonnaire et al., 2019; Rosales-Navarro et al., 2025). Adolescents exposed to emotionally unavailable or highly punitive parenting may seek alternative sources of validation, emotional regulation, and autonomy within digital gaming environments.

Parenting style significantly moderates gaming outcomes. Authoritarian parenting, characterized by excessive control and limited emotional warmth, may provoke oppositional behavior and secrecy, thereby increasing covert gaming. Permissive parenting, on the other hand, often fails to establish clear behavioral boundaries, allowing excessive gaming to escalate unchecked. In contrast, authoritative parenting, which combines emotional warmth with consistent monitoring and collaborative rule-setting, has been shown to reduce the likelihood of addictive gaming behaviors and promote healthier digital habits (Bonnaire et al., 2019).

Importantly, parental modeling of digital behavior also influences adolescents. High parental screen use, often described as "parental phubbing," may reduce emotional availability and normalize excessive digital engagement, indirectly reinforcing adolescents' gaming behavior.

4.2 Indian Sociocultural Context and Academic Stress

Indian adolescents encounter distinctive sociocultural stressors that may intensify vulnerability to Internet Gaming Disorder. The education system is characterized by intense academic competition, high-stakes examinations, and strong parental emphasis on performance and achievement. For many adolescents, academic stress is chronic and accompanied by fear of failure, perceived inadequacy, and limited emotional support.

Within this context, online gaming may serve as a psychologically accessible coping strategy, providing temporary escape, emotional relief, and a sense of mastery that may be lacking in academic or social domains. For adolescents with heightened dopaminergic sensitivity and limited prefrontal regulatory capacity, repeated reliance on gaming for stress relief can rapidly transition into compulsive engagement (Paulus et al., 2018).

Additionally, the gradual shift from joint to nuclear family systems in urban India has altered supervision patterns and reduced opportunities for shared emotional processing. Combined with increasing availability of personal digital devices, these changes create an environment in which excessive gaming can develop with minimal external regulation.

4.3 Peer Relationships and Social Functioning

Peer relationships exert a powerful influence on adolescent behavior and identity formation. Experiences of peer rejection, bullying, social anxiety, or perceived social incompetence are strongly associated with problematic gaming and Internet Gaming Disorder (Paulus et al., 2018). Online gaming environments offer adolescents alternative social identities, peer recognition, and structured social interaction that may feel safer and more controllable than offline relationships.

Multiplayer games, in particular, provide social reinforcement through team membership, status hierarchies, and shared goals. For adolescents with limited offline social success, these virtual interactions may become primary sources of belonging and self-esteem. Over time, reliance on virtual social rewards may reduce motivation for offline engagement, reinforcing avoidance and increasing function-

al impairment.

4.4 Interaction with Neurobiological Vulnerability

Psychosocial stressors such as family conflict, academic pressure, and peer difficulties interact with neurobiological vulnerabilities by increasing emotional distress and reducing regulatory capacity. Stress-related activation of the hypothalamic–pituitary–adrenal (HPA) axis may further sensitize reward circuits and impair prefrontal functioning, amplifying impulsivity and reward-seeking behavior (Weinstein et al., 2017).

Repeated gaming under conditions of stress strengthens maladaptive reward–habit circuits through neuroplastic mechanisms, reinforcing cue-driven behavior and diminishing sensitivity to natural rewards. Thus, psychosocial factors function as contextual amplifiers, accelerating the progression from recreational gaming to disordered use in biologically vulnerable adolescents.

4.5 Summary of the Modulatory Role

In summary, psychosocial and environmental factors shape the developmental trajectory of Internet Gaming Disorder by interacting with adolescent neurobiology rather than replacing it. Family dynamics, sociocultural pressures, and peer environments influence how neurobiological vulnerability is expressed, determining whether gaming remains recreational or evolves into a maladaptive, compulsive pattern. Recognizing this modulatory role is essential for designing effective prevention and intervention strategies that address both biological susceptibility and environmental context.

5. A Neurobiologically Anchored Biopsychosocial Model of Internet Gaming Disorder

While early conceptualizations of Internet Gaming Disorder emphasized psychosocial explanations such as poor self-control, maladaptive coping, or parental failure, contemporary evidence increasingly supports a neurobiologically anchored biopsychosocial model. This perspective recognizes that Internet Gaming Disorder does not arise from a single cause but emerges from dynamic interactions between biological vulnerability, psychological processes, and environmental influences, with neurobiology forming the foundational substrate (Brand et al., 2019).

The Interaction of Person–Affect–Cognition–Execution (I-PACE) model provides a robust theoretical framework for understanding these interactions (Brand et al., 2019). According to this model, individual predispositions—including genetic factors, neurodevelopmental immaturity, dopaminergic reward sensitivity, and serotonergic impulse-control deficits—constitute the core vulnerability. These biological factors shape how adolescents emotionally and cognitively respond to gaming-related stimuli.

Affective responses such as stress relief, excitement, or escape from negative mood states reinforce gaming behavior, while cognitive distortions—such as overvaluation of in-game rewards, perceived social competence in virtual environments, and minimization of real-life consequences—further strengthen engagement. Impairments in executive functioning, particularly inhibitory control and decision-making, reduce the adolescent's ability to regulate gaming behavior effectively (Weinstein et al., 2017).

Environmental factors—including family conflict, academic stress, peer rejection, and sociocultural expectations—do not independently cause Internet Gaming Disorder but act as modulators that amplify or attenuate underlying neurobiological vulnerability. Repeated engagement in gaming under conditions of emotional distress or environmental reinforcement leads to maladaptive neuroplastic changes, strengthening reward–habit circuits and weakening prefrontal control mechanisms. Over time, this process results in a self-perpetuating cycle characterized by craving, tolerance, withdrawal-like symptoms, and functional impairment.

Importantly, this model avoids both biological determinism and psychosocial reductionism. It

acknowledges that while neurobiological vulnerability is primary, environmental interventions can significantly alter developmental trajectories, particularly during adolescence—a period of heightened neural plasticity. Thus, the neurobiologically anchored biopsychosocial model offers a comprehensive and clinically meaningful framework for understanding Internet Gaming Disorder in Indian adolescents.

6. Clinical, Preventive, and Public Health Implications

Conceptualizing Internet Gaming Disorder as a neurobiologically grounded condition has important implications for clinical practice, prevention strategies, and public health policy. At the clinical level, early identification of neurodevelopmental risk markers—such as impulsivity, heightened reward sensitivity, emotional dysregulation, attentional difficulties, and poor sleep regulation—is critical (Paulus et al., 2018). Screening efforts should extend beyond gaming behavior alone to include underlying emotional and neurocognitive vulnerabilities.

Intervention strategies should prioritize family-centered and developmentally informed approaches. Psychoeducation for parents regarding adolescent brain development, reward sensitivity, and the impact of digital reinforcement can reduce blame-oriented attitudes and promote supportive monitoring. Authoritative parenting practices, characterized by emotional warmth, consistent boundaries, and collaborative rule-setting, are particularly effective in reducing excessive gaming (Bonnaire et al., 2019).

Cognitive-behavioral therapy (CBT) remains the most empirically supported psychological intervention for Internet Gaming Disorder. CBT interventions targeting impulse control, cognitive distortions, emotional regulation, and stress management have demonstrated moderate effectiveness, especially when combined with family therapy (Weinstein et al., 2017). Importantly, abrupt and punitive restriction of gaming may exacerbate withdrawal-related distress and oppositional behavior. Gradual reduction strategies, coupled with the introduction of alternative sources of reward—such as physical activity, social engagement, and skill-based hobbies—are more developmentally appropriate.

From a public health perspective, school-based screening programs and mental health literacy initiatives are urgently needed in India. Teachers and school counselors should be trained to recognize early signs of problematic gaming and associated emotional difficulties. Digital literacy programs that emphasize balanced technology use, sleep hygiene, and emotional coping skills may serve as primary prevention strategies.

At the policy level, collaboration between mental health professionals, educators, and policymakers is essential. Regulation of predatory gaming mechanics, age-appropriate content guidelines, and promotion of responsible game design can reduce exposure to high-risk digital environments. Given the scale of adolescent gaming in India, Internet Gaming Disorder should be recognized as a significant public mental health issue requiring coordinated, evidence-based responses.

7. Limitations of Existing Evidence and Future Research Directions

Despite the growing body of literature on Internet Gaming Disorder, several conceptual and methodological limitations constrain current understanding, particularly within the Indian context. First, the majority of neurobiological evidence informing IGD models is derived from Western and East Asian populations. Cultural differences in parenting practices, academic systems, family structures, and digital exposure patterns limit the direct generalizability of these findings to Indian adolescents (Gurjar et al., 2024).

Second, much of the existing research relies on cross-sectional designs, which restrict causal inference. While associations between excessive gaming, neurobiological alterations, and psychosocial difficulties are well documented, it remains unclear whether these neural changes represent pre-existing vulnerabilities or consequences of prolonged gaming behavior (Weinstein et al., 2017). Longitudinal studies tracking adolescents across critical developmental periods are essential to clarify temporal relationships and developmental trajectories.

Third, there is substantial heterogeneity in diagnostic criteria, assessment tools, and cut-off scores used to identify Internet Gaming Disorder. Variability across studies complicates prevalence estimates and limits comparability. Greater standardization, particularly alignment with ICD-11 diagnostic guidelines, is required to enhance methodological rigor and clinical applicability (Brand et al., 2019).

From a neurobiological perspective, future research should adopt multimodal approaches integrating neuroimaging, neurochemical markers, genetic polymorphisms, and neuropsychological assessments. Such approaches would allow for a more comprehensive understanding of individual differences in vulnerability and resilience. In the Indian context, culturally sensitive measures of stress, family dynamics, academic pressure, and digital practices should be incorporated to capture contextual moderators more accurately.

Intervention research also remains limited. There is a pressing need for randomized controlled trials evaluating culturally adapted, family-based, and school-based interventions for IGD in India. Additionally, preventive research focusing on protective factors such as emotional regulation skills, secure attachment, physical activity, and adaptive digital habits may inform early intervention strategies during adolescence, a period of heightened neuroplasticity and behavioral malleability.

8. Conclusion

Internet Gaming Disorder among adolescents represents a complex and multifaceted condition that cannot be adequately explained through purely psychosocial or moralistic frameworks. Accumulating evidence from neuroscience, developmental psychology, and behavioral addiction research indicates that IGD is fundamentally rooted in neurodevelopmental and neurobiological vulnerability, particularly during adolescence a period marked by heightened reward sensitivity and immature executive control systems (Paulus et al., 2018; Weinstein et al., 2017).

Within this framework, environmental and sociocultural factors such as parenting practices, academic pressure, peer relationships, and digital accessibility function as modulators rather than primary causes, shaping the expression, severity, and persistence of gaming-related problems. The neurobiologically anchored biopsychosocial model, particularly as articulated through the I-PACE framework, offers a balanced and integrative understanding that avoids both biological determinism and psychosocial reductionism (Brand et al., 2019).

For the Indian context, where rapid digital expansion intersects with intense educational and familial expectations, this perspective is especially relevant. Recognizing IGD as a legitimate developmental and public mental health concern has important implications for clinical practice, education systems, and policy formulation. Early identification, family-centered interventions, school-based prevention programs, and culturally informed policy initiatives are essential to mitigate long-term psychological, academic, and social consequences.

Ultimately, addressing Internet Gaming Disorder among Indian adolescents requires a shift from blame-oriented narratives toward evidence-based, developmentally informed approaches that acknowledge the central role of the adolescent brain. Such a shift holds promise not only for effective intervention but also for promoting healthier digital engagement and psychosocial development in an increasingly digital society.

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