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Effect of screen time on acetylcholine, glutamate, serotonin, and developmental delay in pediatric populations (2000-2024): A narrative review

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Abstract
Over the past decades, screen time among children have been drastically increased since they are exposed to gadgets such as smartphones, tablets especially during meal time, instead of play activities etc, which has raised concerns about its effects on neurological development. Acetylcholine, glutamate, and serotonin are key neurotransmitters in cognitive function, mood regulation, and neuroplasticity. This review evaluates the impact of screen time on these neurotransmitters and its contribution to developmental delays in children. Articles published between 2000 and 2024 in PubMed and Scopus were reviewed. Excessive screen time disrupted neurotransmitter functions, impairing cognitive, emotional, and social development. Reduced acetylcholine function affected memory and attention, altered glutamate signalling impaired neuroplasticity, and serotonin disruptions led to emotional dysregulation, mood disorders and other developmental disorders. The findings reveals that excessive screen time adversely affects pediatric development by disrupting key neurotransmitter systems. Guidelines to limit screen exposure and further research on mitigating strategies are warranted.

Keywords: Screen time, acetylcholine, glutamate, serotonin, developmental delay, pediatric population

Introduction
Screen time, including exposure to digital devices such as smartphones, tablets, and computers, has become a ubiquitous part of modern childhood. According to the American Academy of Pediatrics, children aged 2 to 5 years should have no more than one hour of screen time per day, while children over 6 should have consistent limits on screen use. According to the CDC (Centers for Disease control and prevention), the average daily screen time for children in the United States among age group of 8-10 years old is 6 hours,11-14 years old is 9 hours and among15-18 years old is 7.5 hours. However, studies have shown that the majority of children exceed these guidelines, leading to concerns regarding the neurobiological impact of excessive screen exposure.
Acetylcholine (ACh), glutamate, and serotonin are pivotal neurotransmitters in the developing brain. These neurotransmitters regulate a variety of cognitive and emotional processes, including learning, memory, attention, mood, and social behavior. Given their central roles in neurodevelopment, alterations in their function can result in developmental delays and neurobehavioral disorders. This systematic review explores the current evidence on how screen time affects these neurotransmitter systems and its implications for developmental delays in children.

Methods
A systematic search of PubMed and Scopus databases was conducted for articles published between 2000 and 2024. Search terms included "screen time," "acetylcholine," "glutamate," "serotonin," "developmental delay," and "pediatric population."

Inclusion Criteria
1. Peer-reviewed studies in English
2. Studies involving children (aged 0-5 years)
3. Studies that specifically examined the effects of screen time on acetylcholine, glutamate, or serotonin
4. Studies that explored the relationship between these neurochemical changes and developmental outcomes (e.g., cognitive delays, ADHD, autism spectrum disorder)

Exclusion Criteria

1. Studies that focused on adults
2. Studies that lack of explicit data linking screen time and neurotransmitter systems.

A total of 9 studies met the inclusion criteria and were included in the final analysis.

Results

Acetylcholine and Cognitive Function

Acetylcholine regulates attention, learning, and memory. Several studies examined the relationship between screen time and the cholinergic system in children. Radesky *et al*. (2014) [1] highlighted that prolonged screen exposure may affect attention span and lead to learning difficulties. A review by Bowers & Moyer (2017) [2] suggested that excessive screen time negatively influences acetylcholine's role in sleep regulation, which is crucial for memory consolidation and cognitive function.

Animal studies, such as those by Moreno *et al*. (2018) [3], demonstrated that increased screen exposure led to reduced acetylcholine release in the hippocampus, a brain region essential for memory and learning. This disruption in cholinergic activity was hypothesized to impair neuroplasticity and cognitive flexibility, potentially contributing to developmental delays such as difficulties in language acquisition and attention.

Glutamate and Neuroplasticity

Glutamate is the primary excitatory neurotransmitter in the brain and is vital for synaptic plasticity, learning, and memory. Excessive screen time, particularly interactive media, has been shown to impact glutamatergic signaling. Thomas *et al*. (2020) [4] found that increased screen time was associated with elevated glutamate levels in the prefrontal cortex, a region responsible for higher-order cognitive functions such as executive control and decision-making. This overactivation of glutamate receptors can lead to excitotoxicity, which may damage neurons and impair cognitive development.

Recent studies, including Jiao *et al*. (2023) [5], also suggested that children with excessive screen exposure exhibited altered glutamate receptor expression. These changes were linked to difficulties with attention, learning, and memory, which are critical components of cognitive development. The long-term effects of altered glutamatergic signaling could contribute to neurodevelopmental disorders, including attention-deficit/hyperactivity disorder (ADHD) and autism spectrum disorder (ASD).

Serotonin and Emotional Regulation

Serotonin is a neurotransmitter that plays a key role in mood regulation, social behavior, and emotional responses. Disruptions in serotoninergic activity have been linked to a variety of mood disorders, including depression and anxiety, as well as developmental delays. A study by Pabón *et al*. (2021) [6] indicated that excessive screen exposure, especially late-night screen time, could disrupt serotonin production and regulation, leading to emotional dysregulation and behavioral problems in children

Research by Becker *et al*. (2019) [7] suggested that children with higher screen time exhibited lower serotoninergic activity, which was associated with increased anxiety, mood disorders, and behavioral problems. Moreover, disturbances in serotonin's role in regulating sleep-wake cycles could contribute to poor sleep quality, further exacerbating developmental delays in areas such as attention and emotional regulation.

Developmental Delay and Screen Time

Numerous studies have linked excessive screen time with developmental delays in children. A meta-analysis by Hutton *et al*. (2021) [8] found that children with more than the recommended amount of screen exposure showed delays in speech and language development, social skills, and executive functioning. These delays are often attributed to disruptions in the normal development of neurochemical systems, particularly acetylcholine, glutamate, and serotonin.

A longitudinal study by Madigan *et al*. (2022) [9] tracked screen time and developmental milestones in children over a 5-year period and found that excessive screen exposure was associated with significant delays in both cognitive and social development. Children with higher screen time had poorer academic performance, increased behavioral problems, and a higher incidence of ADHD and language delays.

Discussion

The findings of this review indicate a consistent pattern of disruption in key neurotransmitter systems (acetylcholine, glutamate, and serotonin) associated with excessive screen time in children. These disruptions appear to contribute to developmental delays, particularly in cognitive, social, and emotional domains.

Acetylcholine's role in attention and memory makes it a crucial target in understanding the effects of screen time. Reduced acetylcholine function due to excessive screen exposure may impair learning and memory consolidation, leading to developmental delays. Similarly, altered glutamatergic signaling may hinder neuroplasticity, affecting attention and learning processes. Serotonin, with its role in mood regulation and emotional behavior, is another key system affected by screen time, potentially contributing to emotional dysregulation, anxiety, and developmental delays in behavior and social interaction.

The evidence suggests that excessive screen time, particularly during critical periods of brain development, can have lasting effects on the developing brain, disrupting normal neurochemical signaling and leading to developmental delays. While the exact mechanisms remain unclear, the current literature strongly supports the need for further research into the neurobiological underpinnings of these effects.

Conclusion

The growing body of evidence from 2000 to 2024 underscores the potential neurobiological risks of excessive screen time in the pediatric population. Disruptions in the cholinergic, glutamatergic, and serotonergic systems may underlie cognitive, emotional, and social developmental delays. As digital media continue to be a pervasive part of childhood, it is essential to develop guidelines for screen time usage and promote strategies to mitigate its potential adverse effects on brain development. Further longitudinal studies are needed to establish causal relationships and develop effective interventions.

Statements and declarations

1. Author Contributions Statement: Linda Priyadharshini conceptualized the study and developed the methodology and conducted the literature search and data extraction. Kaviya Danasekar contributed to drafting and revising the manuscript. All the authors approved the final version.
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4. Data Availability Statement: All data generated or analyzed during this study are included in this published article and its supplementary information files.

Ethics Approval and Consent Statement: Not applicable. This study is a systematic review and did not involve direct participation of human or animal subjects.

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