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CAN DIGITAL MEDIA AND SCREEN TIME INFLUENCE ON CHILDREN'S AND ADOLESCENTS' BRAIN DEVELOPMENT? – AN ARTICLE REVIEW

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ABSTRACT

Objective: Digital media and as a consequence the use of screens are playing an increasingly important role in people's lives. Unfortunately, it also results in screen time among children, which has negative effect for their brain development. The purpose of this article is to present the impact of digital media usage and screen time on brain development and its consequences in children and adolescents.
Methods: The review was conducted based on the analysis of materials collected from the "PubMed" databases. During the search for scientific articles, the following keywords were used: autism in children and screens, child's screen time, advantages and disadvantages of digital media, brain development and digital media, brain development. A total of 30 articles were considered for the study, and their relevance was verified in the context of the impact of digital media on brain development in children and adolescents.
Key findings: Modern digital media play a vital role in 21st – century human life. Despite the many benefits of new technologies, their excessive use can lead to negative consequences. Researchers suggest that this may be related to, among other things, disruptions in brain development and an increase in the incidence of mental disorders.
Conclusions: Most intense development of the human brain occurs in the early years of life, when neurons are particularly plastic and highly sensitive to stimuli. Excessive use of screen devices can affect speech or cognitive development and social-emotional aspects. However, due to rapid technological advances, this issue requires further, in-depth research.

KEYWORDS

Digital Media, Brain Development, Screen Time Exposure, Disadvantages of Digital Media, Advantages of Digital Media

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Introduction

Digital media have been continuously gaining popularity for two decades. They undoubtedly have a significant impact on human life and functioning. This is especially evident among the youngest members of society, for whom the world of the internet and television often provides tools to gain recognition among peers. Young children, spending time in front of screens, not only learn but also give young parents a moment of respite [1, 2]. In Italy, it has been shown that parents often use screens as part of childcare. In the first year of their children's lives, about 30% of caregivers use this method, while in the second year, as many as 70% do [3].

Currently, due to increased availability of various types of media, children spend between 3 to 6 hours a day using screens. This amount of time is comparable to the number of hours spent sleeping in a 24-hour period, which means that, alongside other activities, screen time occupies a significant portion of young people's lives [4]. Scientific studies show that 95% of American teenagers own a mobile phone, and nearly 45% are constantly online [2]. For example, the rate of screen use among children aged 2 to 4 years in the United States increased from 39% to 80% between 2011 and 2013. In England, more than half of children under one year of age spend time in front of a screen daily, while in Italy, already one-fifth of toddlers use a mobile phone during their first twelve months of life [3].

The beneficial impact of electronics and their contribution to the continuous development of humanity cannot be underestimated [5]. For many years, digital media have facilitated daily functioning and provided entertainment through the distribution of movies and computer games [2]. However, it should be noted that digital media, on one hand, have many advantages, but on the other hand, they carry negative consequences resulting from their excessive use [6].

For years, humanity has been wondering about the impact digital media have on the rapidly developing young organism. The discussions mainly focus on the amount of time spent in front of screens, due to differing opinions regarding its quality. Two types of engagement during screen use are distinguished: passive and active

[7]. Passive engagement is defined as the lack of physical participation and interaction with the screen. On the other hand, active forms of spending this time include playing games, where a person uses their cognitive abilities [3]. There is evidence of the positive effects of active participation, such as the development of language or creativity, while passive screen use may be a precursor to many negative consequences [7].

Children who excessively use screens are exposed, among other things, to the influence of media messages, which can affect their behavior, sleep, slow down neuronal development, and hinder the learning process that develops best through social interactions [1]. Furthermore, numerous studies highlight effects such as mood swings, delayed speech development, and the occurrence of autism spectrum disorders. It is also worth mentioning that due to the behavior of children who overuse digital media, their relationships with parents may suffer, leading to further developmental consequences [4]. Another very important fact is that screen use not only negatively affects the functioning of the human body but also its structure, as observed in studies of the brains of preschool-aged children. These scientific research showed, among other things, thinning of the gray matter in the cerebral cortex [1].

The human brain is the most unexplored organ of the human body. Its greatest development occurs during the early years of a child's life. In the first year, the brain doubles in volume, and by the second year, it reaches about 80% of the size of an adult brain, forming key structural and functional foundations during this time. Its development takes place through the remodeling and reorganization of neural networks, which are shaped by both genetic and environmental factors . It is during this period that neurons are most plastic and susceptible to shaping, and the future development of the child largely depends on the parents [1]. Excessive, uncontrolled screen use at a young age can have a significant impact on the functioning of the child's nervous system [5].

A very important issue is understanding the current problem of electronics use and its consequences, especially given the continuous increase in technology use, which was reflected during the COVID-19 pandemic in 2019 [2]. This paper aims to review the available knowledge on the neuropsychological and psychosocial consequences of digital media exposure during childhood and adolescence.

Methodology

The review was conducted based on the analysis of materials collected from the "PubMed" databases. During the search for scientific articles, the following keywords were used: autism in children and screens, child's screen time, advantages and disadvantages of digital media, brain development and digital media, brain development. A total of 30 articles were considered for the study, and their relevance was verified in the context of the impact of digital media on brain development in children and adolescents.

Results

Outline of the physiological development of the brain

Childhood is a time of intensive growth and changes in the human nervous system, so that cognitive and affective functions such as attention, memory, emotion and the reward system develop [1, 8]. The brain in early childhood is characterized by high experience-dependent synaptic plasticity and prolonged myelination, which is very important in the maturation of brain networks [5, 9]. In children up to the age of 6, brain development at the cellular level involves nerve cell proliferation and migration, myelination, programmed cell death, the formation of dendrite branching and synaptic connections, as well as their removal [10]. During the transition age from childhood to adolescence, many changes and processes take place in the human body, such as further myelination in the nervous system, strengthening of already existing synaptic connections, and synaptic pruning, which indicates maturation of the cerebral cortex. Environmental factors have a very important role in regulating the pruning of synapses during adolescence, which were produced in excessive amounts during childhood [11].

Individual areas in the brain, such as cortical thickness, gray matter volume, functional activation, and the connectivity of large networks, have specific maturation timelines and sequences of changes, which in turn affect behavior and intellectual abilities [8]. For example, neuroimaging studies have shown that unimodal cortical areas mature faster (e.g., visual, sensorimotor) than polymodal areas or later-maturing higher-order prefrontal regions [8, 12]. Regarding the development of cognitive and affective functions, attentional capacity develops faster than working memory, which matures over a longer period, while emotional perception develops earlier than emotional regulation [8].

The brain volume growth spurt begins as early as mid-pregnancy, reaching its peak for gray matter before the age of 6, and for white matter before the age of 29. The volume of subcortical gray matter peaks

around the age of 14. Total brain volume is largest at 11–12 years of age (typically earlier in girls than in boys), while cortical thickness peaks at around 1.7 years old [1, 13]. Regarding the maturation of subcortical structures, the amygdala matures first (at 3.3 years), followed by the hippocampus (4.6 years), then the putamen (4.6 years), globus pallidus (5 years), and caudate nucleus (5.5 years). The thalamus has the longest maturation period, lasting approximately 7.3 to 7.5 years [10].

The increase in brain volume is accompanied by the development of neural networks in the brain, which is essential for proper later functioning. Structural and functional brain networks mature most rapidly into highly developed and efficient systems during the first few years of life. Individual neural circuits in the brain develop independently before connecting and enabling cooperation between each other. This ongoing integration of networks is a hallmark of brain network maturation [9]. Prolonged screen time can negatively affect the microstructural integrity of white matter pathways, which impacts language abilities, executive functions, and reading and writing skills in children aged 3 to 5 years [14, 15]. Screening tests assessing the development of children at ages 3 and 5 showed poorer outcomes for those who spent more time in front of screens around the age of 2 [14].

Executive functions include higher-order cognitive skills, whose proper development is essential for adequate self-regulation, learning, and also impacts mental health. They develop most intensively during the first years of life. Together with the prefrontal cortex, these functions are extremely sensitive to the surrounding environment during this period. Images presented on two-dimensional screens, often intended for older children or adults, are difficult for young children to process, which exposes them to deficits in executive functions due to underdeveloped processing skills and cognitive functions [15]. Research indicates that watching videos activates brain neurons to a lesser extent than looking at illustrated books [9].

Changes occurring in the brain as a result of children's media use

In a study conducted by Huang P. et al., the impact of screen exposure in children up to 4 years old on neurons, brain network topology, and socio-emotional competencies at a later age was examined. The study found a correlation between the time spent in front of screens and the integration of emotion-processing and cognitive control networks in participants at 6 years old. This may result in greater emotional dysregulation and poorer socio-emotional competence due to the premature maturation of brain networks caused by excessive stimulation [9]. Moreover, a study conducted by Nivins S. et al. showed that individuals who spend a significant amount of time on social media may experience accelerated synaptic pruning and changes in the myelination process, which could potentially lead to a reduction in cerebellar volume in the future. On the other hand, it has been demonstrated that the use of digital media does not significantly affect the development of cortical surface area and striatal volume [11]. Both in preschool-aged children and those around 10 years old, it was observed that those who spent more time using media had a thinner layer of cortical gray matter and shallower sulcal depth in areas responsible for visual processing, social cognition, attention, and developing reading and writing skills [1]. This thinning of sensory areas in the brain can be associated with maturation, while greater cortical thickness and sulcal depth indicate the extent of cognitive functions in children and adolescents. Moreover, reduced cortical thickness in the angular gyrus may be linked in adulthood to decreased social cognition and episodic memory. This gyrus is responsible for the ability to recognize written letters and for preparing children to learn to read, and a reduction in this parameter may indicate impaired development of these skills [12]. It is worth noting that digital media not only directly influence changes in children's development but also indirectly by reducing the time spent with peers, leading to social isolation. This social isolation also causes structural and functional changes in the brain, which most significantly affect social cognition and emotional regulation [5].

Advantages and disadvantages of screen use

In the 21st century, the benefits of digital media are indispensable. The Internet is an essential tool for work, education, and access to public services. It enables employees to perform their professional duties remotely and allows students to learn online. Additionally, access to public services, such as electronic banking and scheduling medical appointments, has become faster and more convenient thanks to digital tools [16, 17].

Moreover, digital media enable users to shape their online identity, providing a sense of freedom and control, especially for the generation raised on the internet. The possibility of maintaining complete anonymity without fear of judgment from others is also appealing, allowing less confident individuals to initiate and build interpersonal relationships. Additionally, one can gain a sense of belonging by joining groups that share similar

interests and beliefs, which is why games often foster such connections. However, one of the most important advantages of using digital media is the ability to interact with others on an unprecedented scale, regardless of the continent on which a person is located. This facilitation of communication offers many opportunities for social, cultural, and professional development. All of the above features are significant benefits that have brought the world to a higher technological level; however, due to their attractiveness, they often lead to addiction [16, 18].

Addiction of children to spending excessive amounts of time in front of phone, tablet, and television screens can cause serious health problems, particularly in the areas of cognitive, language, and socio-emotional development [19].

Cognitive development

The use of screen media can have both positive and negative effects on a child's cognitive development. Among the positive aspects are education, due to the easy and quick access to information, as well as the availability of specific educational applications, such as apps for learning to read or electronic books [18].

On the other hand, negative effects have been observed, including problems in sensorimotor development, executive functions, and academic performance [19]. A cohort study, the Quebec Longitudinal Study of Child Development, showed that excessive television use at the age of 2 was associated with decreased engagement during lessons and lower math achievement in fourth grade. Similar results were obtained in studies conducted in Spain and the USA. Additionally, among teenagers, it was found that multitasking with media was negatively associated with working memory and the ability to switch between tasks [18].

Hendry and colleagues conducted a study involving 575 children in the United Kingdom aged 8 to 36 months. In this scientific research, the authors observed that not only the amount of screen time but also the content of digital media affects children's cognitive development. It was demonstrated that time spent in front of screens during early childhood is associated with lower cognitive performance, particularly in executive functions and regulatory skills. It is also worth noting that fast-paced, aggressive, and distracting content can weaken a child's ability to concentrate. The results suggest that exposure to and assimilation of such stimuli often lead to a need for similar stimulation in real life. This translates into reduced concentration in classroom settings and other educational environments, impairing the ability to absorb knowledge. Furthermore, it was shown that prolonged screen exposure significantly contributes to a decrease in working memory capacity in children, causing difficulties in handling complex tasks [20].

Bukhalenkova and Almazova conducted a study involving 772 mothers of children aged 5 to 6 years, examining the relationship between active screen time such as playing computer games and parents' active participation in these activities. The conclusion was that prolonged screen use limits children's creativity and problem-solving skills [20].

Speech development

Another important aspect in the context of digital media use is speech development in children. Researchers from the Department of Psychology and Speech and Language Pathology, Faculty of Medicine, University of Helsinki, investigated the impact of screen time on language skills. The study involved 164 Finnish children aged 2.5 to 4.1 years and their mothers. A negative relationship was found between the time children spent alone in front of screens and their expressive language abilities as well as overall language skills. Furthermore, it was shown that the more time spent in front of screens, the poorer the language abilities [21]. Confirmation of these findings comes from another study conducted in Canada by McArthur and colleagues, involving 1,994 mothers with children aged 36 months. The study compared the impact of different levels of screen time (≤1, 2, and ≥3 hours per day) on toddlers' development and behavior. The results showed that exceeding the WHO's recommended one hour per day is associated with a higher risk of emotional problems and developmental delays, especially in language acquisition, with the most severe effects occurring at over 3 hours per day. Therefore, it is important to limit screen time, support parents in managing it, and promote activities that foster the child's development [22].

Moreover, as previously mentioned, interactions between children and adults are crucial for the proper development of lexical abilities and overall language development. Time spent in front of screens can reduce the quantity and quality of child-parent interactions, which hinders the youngest children from further developing their language skills [21, 23]. Educational programs and co-viewing television with a parent, on the other hand, can have a positive impact on vocabulary learning. The age at which screen use begins is also

significant, as the later the exposure to screens occurs, the better the language development. This aligns with pediatric guidelines that recommend protecting children from digital media use until the age of 18 months, and for children over 18 months, limiting screen time [7].

Unfortunately, the primary way young children currently use digital media is passive television watching, which further limits opportunities for language interactions [21]. However, there is evidence that the level of screen interactivity may also positively correlate with the development of a child's language abilities [24]. Hu et al. studied the relationship between active and passive screen time in children. The research involved 579 Chinese children aged 5 years. They confirmed that passive screen time negatively affects executive functions, which include planning, problem-solving, attention control, flexibility, and social skills. In contrast, interactions with screens stimulate the development of receptive language abilities [20].

In the context of speech development, it has also been found that excessive visual and auditory stimulation during screen media use can distract children, further hindering the differentiation of phonological and syntactic sounds. This is additional evidence of the impact of television on poorer language skills development [20]. Medawar and colleagues, in a study conducted with 465 mothers of children aged 0–36 months, found that passive exposure to screen content negatively affects language and reading skills. The constant influx of auditory and visual stimuli from screens makes it difficult for children to maintain concentration and attention, which adversely affects the learning process [20].

Finally, it is important to emphasize that language development is influenced not only by the amount of time spent in front of screens but also by the quality of the content viewed, which may correlate with a smaller vocabulary. Poor quality is defined as: watching television alone, watching content intended for adults, having the television on in the background, and early age of viewing [24].

Social-emotional development

The amount of time spent in front of screens has been linked to an increase in obesity problems, sleep issues, anxiety levels, and depression [19]. Studies conducted on very young children suggest that screen use is an independent factor reducing mental well-being. It has been shown that increased time spent watching television between 6 and 18 months of age may cause greater emotional reactivity, higher levels of aggression, and more frequent externalizing behaviors [25]. Moreover, digital media can have varying effects on children depending on gender, as evidenced by the fact that gaming reduced emotional understanding in boys but not in girls [19, 26]. The same effect in 6-year-old girls was caused by watching TV at age 4, while having a television in the child's bedroom at age 6 is associated with lower emotional understanding at age 8 [26]. Halpin et al. conducted a study in Australia involving 106 parents (aged 18 or older) and children aged 0–4 years, demonstrating that prolonged screen use, besides reducing children's time management abilities as well as concentration and planning skills, also adversely affects their ability to recognize and regulate emotions [20].

Using computers and video games is associated with serious depressive disorders later in life. However, the same is not observed after exposure to TV. Regarding video games specifically, their use by children may be linked to the occurrence of anxiety disorders [25]. Depressive symptoms, as well as suicidal thoughts, can also result from sleep deprivation caused by time spent in front of screens, using digital media at night, and smartphone addiction [27]. It is also worth mentioning that not only the amount of time spent on digital media or exposure to multimedia device screens are responsible for these problems, but also cyberbullying experienced by children and adolescents online, as well as media addiction, contribute to the deterioration of mental health and even to suicide attempts [28].

Early and increased exposure to violent content may be associated with a higher incidence of antisocial behaviors. Additionally, violent and fast-paced content triggers dopamine pathways in the brain that stimulate the reward system, which may be linked to the development of ADHD [27]. Moreover, a meta-analysis by Werling A. et al. indicates that children and adolescents diagnosed with ADHD are at increased risk of problematic internet and media use [29]. Therefore, the relationship between digital media use and ADHD is bidirectional, meaning that media influence later ADHD symptoms (such as impulsivity, inattention, and hyperactivity), and individuals with ADHD are more prone to excessive exposure to multimedia device screens [30]. Furthermore, addiction to multimedia screens can also cause psychoneurological effects, including decreased ability to cope in social situations and the development of craving behaviors resembling substance addiction [27].

It cannot be denied that social media serves as a means for young people to maintain friendships, which can have a positive effect on their relationships with others [28]. On the other hand, however, prolonged time spent in front of screens leads to a decrease in the intensity of face-to-face relationship building. Additionally,

teenagers' use of social media distorts their definitions of social acceptance, simplifying it to the number of likes and friends on social platforms. Unfortunately, this often leads to constant comparison with others, feelings of inadequacy, and the generation of anxiety disorders [25]. Moreover, overuse of technology by both children and parents negatively affects their mutual interactions throughout the day, emotional self-regulation, and causes parental distraction, which may result in missing certain signals from their children, further leading to unmet needs of the offspring. Both the time spent in front of screens itself and poorer emotional regulation, cognitive abilities, behavioral control, and attention span contribute to worse social outcomes, all of which are consequences of digital media use [20].

Autism

A systematic review of 11 studies conducted by Sarfraz and colleagues from the California Institute of Behavioral Neurology and Psychology analyzed the relationship between children's screen exposure time and the development of autism spectrum disorder (ASD). Most of the studies confirmed that longer screen time significantly increases the risk of ASD symptoms. For example, children who spent more than 3 hours per day in front of screens scored higher on ASD screening tools, such as the M-CHAT-R, compared to children with shorter exposure times. Furthermore, children exposed to screens from an early age exhibited more frequent problems with social communication, speech delays, difficulties in understanding nonverbal communication, and behaviors typical of ASD. The studies showed that reducing exposure led to an improvement in symptoms [6].

For example, in Kurdistan, Iraq, Mosa and colleagues studied 231 children diagnosed with autism spectrum disorder to examine the correlation between screen time and the likelihood of developing these disorders. Most participants began using screens within the first two years of life, with a significant proportion exposed before the age of one. Some studies indicate that early exposure to screens relevantly increases the risk of ASD, while others do not find such a link. The authors of this study did not find statistical significance for this parameter. However, the average daily screen time for children with ASD was notable, at 3.61 hours, which was significantly higher than in the control group, where the average was 2.99 hours [4].

Furthermore, Alrahili and colleagues also confirmed a statistically significant association between screen time and ASD symptoms in children. The study involved 308 children aged 4 to 6 years. A significant correlation was revealed between the number of hours spent daily on electronic devices and an SCQ score above 15, suggesting that children using these devices for more than 3 hours per day may exhibit ASD-like symptoms [17]. At the same time, some studies have not confirmed a significant relationship between screen time and ASD, indicating the need for further research in this area [4, 6].

Discussion and Conclusion

In summary, in the 21st century, electronic devices play an indispensable role in human life, often accompanying individuals for up to 90% of their waking time. Unfortunately, there is scientific evidence indicating the negative impact of digital media on the sensitive, developing organism. Exceeding the screen time recommended by the WHO can lead to long-term effects, such as speech development disorders or symptoms within the autism spectrum. The human body is extremely complex, so the influence of media, such as television, on a child and its consequences depend on many external factors, including gender, age, and whether viewing occurs alone or together with others. Therefore, it is crucial to conduct further research on the impact of digital media on the development of children and adolescents, as well as to deepen parental education on the consequences of children's screen addiction.

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