The Impact of Screen Time on Working Memory Function of Children and Adolescents

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Abstract. Due to rapid advances in science and technology, there has been an alarming increase in the amount of time people spend in front of screens, including watching television and using smartphones and tablets. The physical and psychological effects of screen use have been well studied, and excessive screen use is often strongly associated with poor physical activity, lack of concentration, and diminished memory function. The public also recognizes that screen time should be limited in order to maintain better health. However, since viewing (passive screen time) and using smart devices (active screen time) are also correlated with exercising cognitive and executive abilities, computer games that enhance working memory skills are associated with better verbal and spatial memory skills. As the development of working memory is often considered crucial during childhood and adolescence, but also in the context of weaker self-regulation (difficulty in controlling the amount of time spent on screens on their own), the purpose of this paper is to review articles that assess whether time spent using screens affects children and adolescents' working memory performance. The results of this review showed the following finding: screen time, when used properly, has a positive effect on memory (e.g., reading and text comprehension when using educational applications), but memory function can be impaired to varying degrees with prolonged screen use (e.g. impaired active imagery ability).

Keywords: Working Memory · Screen Time · Children · Adolescents · Correlation

1 Introduction

As all aspects of people's lives are strongly associated with using electronic devices, there is a growing general agreement that excessive use of electronic devices raises the risk of behavioral, cognitive, and emotional problems, and emotional problems, including in children and adolescents. With a longer exposure time to screens, an increase in attentional issues was found in teenagers [1]. Children today are increasingly subjected to and utilize electronics from an extremely young age. The World Health Organization (WHO) recommends to have as modest amounts of recreational screen time [2]. Other organizations, for example, the American Academy of Pediatrics (AAP), advised children and adolescents to restrict their screen usage to two hours per day [3, 4].

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Children born after 2000 were reported to start watching television generally at four months old [5]. A finding demonstrated by researchers proved that minors aged 4 to 13 years were tested on their cognitive abilities, including working and short-term memory, language and spatial capabilities, after using a touch screen tablet. Short-term and working memory, especially visuospatial sketchpad, have positively correlated with tablet-based assessments [1, 6]. Tablets contain thousands of free educational apps designed for children. Youngsters, over other electronic devices, often prefer them due to their versatility, ergonomic design, and engaging and diverse sensory stimulation, making them appealing to preschoolers [7].

Literature has also shown that MRI experiments tested that screen light changes brain regions associated with working memory (i.e., higher-order cortical and alertness-related subcortical regions) [8]. Similarly, studies have shown that children between 3 to 5 years old who have excessive screen time use beyond the AAP recommended limit affected measurements of brain white matter tract microstructural architecture and myelination that promote language and emerging literacy skills, as well as related cognitive evaluations [9].

Time spent at home has grown as due to covid-19, online teaching has become a standard method of education in schools and courses, and the internet has become a primary medium for learning about one's surroundings and boosting interpersonal relationships. According to studies, recreational screen time grew by 61.2 min per day for kids aged 4 to 17, while it increased by a startling 247.2 min per day for minors aged 6 to 17 in China [10, 11].

2 Methodology

A systematic literature search was carried out utilizing the databases Web of Knowledge, the National Center for Biotechnology Information (NCBI), JSTOR and Google Scholar. Regarding screen time, the following search phrases (and their variations) were entered: "screen time", "excessive", "addictive", "brain health", "device", "phone", "computer" and "tablet". Age-specific terms include: "children", "adolescents" and "teenage", working memory terms include: "cognitive", "central executive", "visuospatial" and "phonological".The following inclusion criteria were used to identify studies. Studies have to (i) include empirical data (ranging from case studies to surveys), (ii) published after 2000, and (iii) include analyses pertaining to connections between screen time and memory capacities of children and adolescents. A total of 19 articles have been selected and included in this paper.

3 The Impact of Screen Time on Working Memory

3.1 The Definition of Memory Function

Memory is described as the ability of the human brain to store information, a process that typically entails encoding, storing, and retrieving collected information. Atkinson and Shiffrin's multi-store memory model [12] and the Baddeley and Hitch proposed working memory model are the two most commonly studied memory models in research.

Memory is divided into three categories in the multi-store model: sensory memory store, short-term memory store and long-term memory store. It is believed that sensory memory constantly gathers information from its surroundings and lasts approximately 0.25 to 0.5 s. Short-term memory is limited in memory capacity for about seven plus or minus two items [14], storage duration (maintains 15 to 30 s) [12], and sound encoding capabilities [15]. Long-term memory is unlimited in duration and capacity and encodes information mostly in semantics.

Working memory (WM) refers to the ability to acquire and retain informational knowledge throughout time while executing a specific task, which would then be retrieved, modified, and rearranged [16]. It contains a central executive (assign information to go to different stores), visuospatial sketchpad (operate information in visual and spatial structure) and phonological loop (process and store verbal information). Working memory, as opposed to long-term memory, refers to the tiny quantity of knowledge that may have been kept in mind and used to accomplish cognitive activities. Working memory is one of the most commonly discussed psychological concepts. It is commonly associated with or related to intellect, information processing, executive functioning, interpretation, analytical thinking, and knowledge acquisition, and it lasts throughout life [17]. Working memory requires vital information, switching between different sets of thoughts, and blocking information considered less relevant than was previously involved in working memory [18]. It is considered that working memory performance is unpredictable and susceptible to various social and environmental circumstances, including sleep, pressure, and some mental diseases [19].

3.2 The Impact of Screen Time on Working Memory

There is much debate over the influence of screen usage on working memory. The perspectives can be characterized as an adverse effect of screen time on memory, a beneficial effect on memory, or no apparent connection between the two [19, 20]. It is also considered that the correlation between activities before the screen and cognitive development changes throughout a person's adolescence [19].

Screen time refers to the time spent using electronic screens to watch TV, use the Internet, and play video games. In order to differentiate different types of screen time, the forms of screen time usage can be roughly divided into active screen time (i.e., using smartphones, tablets and computers, playing video games), which involves interaction and passive screen time (i.e., watching television). It is reported that parents show negative views toward smart electronic devices as they worry about the kids' possible physiological and psychological issues [21].

3.2.1 The Negative Influence of Screen Time on Working Memory

Much study has been undertaken on the detrimental consequences of screen time on children and adolescents working memory. According to a meta-analysis of a range of experimental and quasi-experimental studies ($n = 23$), explicit learning on working memory tasks is related to increases in such abilities during infancy and adolescence, and excessive screen time may damage the working memory abilities [19]. The time spent on screen usage will likely replace the time spent on in-person interaction, including

parental interaction and between-peers interaction. It may lead to deficits in behaviors such as language development [21]. For example, it has been reported that language ability progresses slowly when young children spend more time watching television [5].

As mentioned, passive screen time and active time differ in the form of interaction with the screen. Visual and auditory senses are the two most essential senses during screen use, and interactions with the devices often replace actual conversations. The developmental influence of preschoolers exposed to television and smart technologies on language and literacy development should be examined (phonological loop). Because this engagement frequently substitutes genuine speech, the developmental impact of preschoolers exposed to television and screens should indeed be evaluated in terms of language and reading acquisition [7].

It has been proved by Danet et al. that children of an average age of 3.8 years have shown weakened memory function after using electronic devices to stream videos and use applications [22]. Neophytou, Manwell & Eikelboom conducted a scoping review by reinvestigating 44 articles on the consequences of excessive screen time on memory, mainly in teenagers, from databases including PubMed, PsycInfo, and Google Scholar [1]. According to the findings of this study, excessive screen usage might negatively impact the development of working memory, especially in children and adolescents. Studies included in the review have pointed out that exposure to screens (which contain lights and sounds) immoderately can induce a decline in both short-term and long-term memory and various cognitive functions [23, 24]. Significant differences were detected in the preschoolers' group in a range of neuropsychological activities and also at the level of trends in auditory information processing indices, and those who were not overly involved in the internet performed better in storytelling activities, indicating that the group with less online engagement outperformed the others [7].

Not only in the phonological loop but excessive use of screens also causes lower performance in mental imagery performance [25]. The mental imagery accuracy was lower in subjects between 3 and 10 years old who spent more time using the screen. No mental imagery difference was found between active and passive screen time usage. Screen time does not improve mental imaging ability when mental comparisons of visual/haptic pictures are required. Although many applications on smartphones and tablets have advertised the involvement and practice of imagination of the younger audience, the active use of screens can be criticized for having less active imagery ability compared with everyday activities such as reading.

Similar findings have also been demonstrated by Pitchford & Outhwaite [6]. Minors aged 4 to 13 years were tested on their cognitive abilities, including short -term, working memory, language and spatial capabilities and, after using a touch screen tablet. Short-term and working memory, especially visuospatial sketchpad, shown a positive correlation with tablet-based assessments. Comparably, screen time at the age of two is adversely connected to the development of executive abilities in infancy and childhood from the ages of two to three (when adjusting for a variety of factors such as language ability) [26].

3.2.2 The Positive Influence of Screen Time on Working Memory

Relatively, the studies on the positive outcome of screen usage time on working memory in children and adolescents also occupies a part of the field. Cajochen et al. discovered that the LED-backlit screen emitted the light can have a positive effect on working memory needs, whilst indicated by rapid production and dissemination of supra-second frequency ranges (5–15 s), along with declarative memory, as evidenced by improved awareness of recent acquisition of language items [8]. Hence, the findings indicate that the LED-backlit screen outperforms other screens in terms of cognitive function in the evening. It was also found by Small et al. [27].

Furthermore, Small et al. found that children aged 4 to 6 years showed improved performance on working memory tasks after completing computerized training (i.e., CogMed), which is a technique often applied in training working memory that requires visuomotor control [27]. In addition, researchers may found positive and non-significant relationship between the screen time and working memory. For example, Zhang et al. studied the connection between screen time (both active screen usage and passive screen usage) and cognitive development (measured with Early Years Toolbox) of 97 toddlers aged 3 to 5 years [28]. The result found that no significant connection between television and video screen time with working memory. The greater the screen time, however, the lesser the likelihood of having stronger working memory, and adherence to maintaining screen use time within the recommendations helped enhance working memory. In addition, this study refuted the correlation between screen time and word use regardless of the type of intelligent electronic device used. The researchers explained that the result could be affected by the quality of the screen experience. A limitation of Zhang et al.'s research can be found as executive function is a lesser-known component of the working memory model, and the influence of screen time on cognitive performance may vary over developmental stages as its role is more recognized.

Soares et al. founding further supported the above results [19]. They analyzed the performance of 3625 teenager participants at different age stages, presented the results of the study by assessing the use of three distinct forms of screen time: watching television, playing videogames, and operating on the computer as well as the participants' reverse digit span test to examine the subjects' working memory. The following results not only showed the positive and negative outcomes, but also presented the non-significant relationship between screen use and working memory. Firstly, the results in a previous study about television viewing showed differences in performance on the screen-use time and digit span tests by gender. Participants in the male group who had one additional unit of screen time per day at 11 improved their mean score on the reverse digit span test by 0.09 points later. Secondly, in the video game playing situation, the male participants who had one additional unit of screen time per day at 11 improved their mean score on the reverse digit span test by 0.09 points an older age. Again, no clear associations were found in the female group. Finally, the amount of time boys spent using computers between the ages of 11 and 15 revealed a strong correlation to their backward Digit Span performance. However, this was moderated by Intelligence Quotient (IQ) at 18. This link once more did not show in the female participants. To conclude, this longitudinal study pointed out the gender disparities in the relationship between working memory and screen time, with males showing a more substantial direct and pronounced influence

than women. Furthermore, the impacts of screen time were mediated by characteristics that include IQ.

4 Implications

Several criticisms have been put forward on the difference between various points of view on the topic. First, it is known that working memory develops with age, and working memory's fundamental modular structure is evident as early as age six and steadily evolves throughout puberty. A model consisting of three different but related variables is similar to the working memory model and adequately fits the data [29], and this may imply that investigations with very young participants (i.e., 2 or 3 years old) may be invalid and less appropriate because their working memory model is still a poorly developed component for infants. The working memory capacity of infants cannot be adequately assessed; therefore, its validity may be questioned, and the results may be difficult to replicate. Second, the public's perception that prolonged screen viewing and use affects memory may have been misguided and resulted in biased predictions. In Zapata-Lamana et al.'s study of the effects of increased screen time on school performance, the authors found that students self-perceived a decline in memory capacity when they spent relatively long periods using screens this self-perception being particularly pronounced among female subjects [30]. However, unlike self-perceptions, longer screen time did not significantly affect memory tasks, and female subjects had lower self-perceptions but better school performance related to memory. Since many of the influences of screen time on memory incorporate self-reported outcomes (e.g., screen usage), biased perceptions could potentially misrepresent the actual results. Third, the effect of screen time on memory may be influenced by other factors that are not considered in this paper. For example, longer screen time may imply less irregular sleep, unhealthy lifestyle habits, and fewer outdoor and interpersonal interactions (too homogeneous a cognitive-developmental situation). Such factors may result in slowing development and impairing cognitive function during the critical period of cognitive development in the brain of children and adolescents.

5 Conclusion

In summary, this paper reviews the literature from previous years. It synthesizes whether screen time use effects on memory function in order to make recommendations for children to promote positive cognitive development as they grow up. The perspectives reviewed in this paper have been divided into those in which screen time negatively affects working memory and those in which screen time has a positive or no effect on working memory. Although many studies in the field have confirmed the different perspectives, this paper only explores them in terms of one item, memory function, because controlling screen time does not only have a possible effect on memory. Several studies have shown far-reaching effects on aspects such as attention and possibly addictive behavior.

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