ADDICTION & SOCIAL MEDIA COMMUNICATION

Techno-mediated cognitive processes

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ABSTRACT

Background: Progress in digital technologies has changed the way people interact with the world, affecting cognition through neuroplastic changes. The impact of digital media use is particularly marked among adolescents, increasing worries about attention, memory and multitasking abilities. Current studies reveal both positive and negative cognitive implications, with potential consequences for long-term development and well-being.
Method: This review summarises the results of recent studies on the effects of digital technologies on cognitive processes, focusing on attention, multitasking and memory. Empirical data, meta-analyses and neuroimaging studies were examined to explore the neural, behavioural and psychological impacts of digital media use in different populations.
Results: Excessive use of technology, especially in adolescents, is related to deficits in attention, memory and multitasking. Overuse of screens is linked to changes in brain regions responsible for regulating attention and working memory. However, targeted digital interventions, such as game-based training, have shown the potential to improve cognitive abilities.
Conclusion: Digital technologies present a double-edged influence on cognition, offering opportunities for cognitive improvement but increasing risks of impairment when overused. Promoting critical and informed use of technology is crucial to manage its impact on cognitive development and well-being. Further research is needed to develop strategies that maximise the benefits and reduce the risks of the new digital society.

Keywords: *Cognitive processes, technologies, adolescence.*

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Introduction

In recent years, the use of technology has become an integral part of everyday life, especially for the younger generations, who live in an incomparable technological environment. From the first modems of the 1960s to the ultra-fast connections of today, the web has overcome all geographical and social barriers, connecting billions of people in a global network of information and opportunities. Smartphones, social platforms, video games and online research are not just instruments for communication or entertainment, but are progressively transforming the way the brain processes, memorises and uses information. It is known that the brain, thanks to its neuroplastic ability, can modify its neuronal architecture in the long term according to stimuli from the outside world. (Rugnetta, 2024).

Although early evidence has shown that the continuous use of technology has both favourable and unfavourable effects on brain function and behaviour (Small et al., 2020; Haddock et al, 2022), this phenomenon has attracted increasing scientific interest, raising questions about the potential cognitive implications of excessive technology use.

Implications for cognitive aspects

Although technology use is common among all age groups, adolescents are the most affected category. A 2023 Pew Research Center survey (Anderson et al., 2023) of more than 1,000 US teenagers reveals the extensive use of social media, identifying YouTube, TikTok, Snapchat and Instagram as the most popular platforms. About a third of the sample uses at least one of these 'almost constantly', with significant differences by gender, ethnicity and economic income. Black and Hispanic teenagers spend more time online than whites, while access to technology devices, such as computers and tablets, differs by family income.

Sensory stimulation resulting from excessive screen use could cause changes in the structure of the developing brain (Paulus et al., 2019). In line with this, the study by Onyeaka et al. (2022) showed that adolescents who spend at least 3 hours a day in front of screens for playful purposes show a significantly higher probability of developing cognitive difficulties, such as problems with attention, memory and decision making.

Methodology

A narrative approach was taken in this literature review, with the aim of exploring the relationship between the use of digital technologies and cognitive processes. The search was conducted between September and December 2024 in the PubMed, PsycINFO, Scopus, and Google Scholar databases. Combined search terms such as "Internet Addiction AND cognitive functions" were used, selected on the basis of their thematic relevance. Inclusion criteria included: English-language articles, published between 2009 and 2024, presenting empirical data, narrative or systematic reviews relevant to the objectives of this analysis. Articles with unrelated content were excluded.

The initial selection generated approximately 487 results. After removal of duplicates and reading of abstracts by two researchers, 36 articles were selected as relevant. All articles were read in full by at least two authors of this paper. The information that emerged was organized thematically, divided by cognitive area (memory, attention, multitasking), with a critical analysis of the main evidence and the most relevant theoretical perspectives.

Multitasking

Multitasking has been defined in scientific literature as the ability to perform or manage several cognitive or physical activities simultaneously or in rapid succession, alternating attention between them. This process, made increasingly frequent by the extensive use of technology, has been the subject of numerous studies highlighting its negative impact on cognitive performance (Van Der Schuur et al., 2015; Bohle et al.,2019; Firth et al, 2019). Imaging studies have shown neural differences in relation to cognitive deficits associated with media multitasking. Moisala et al. (2016) showed that frequent multitaskers exhibit greater activation of right prefrontal regions involved in distraction management, with worse performance on attention tasks, indicating greater cognitive effort required to maintain concentration. Furthermore, high levels of Internet use (Kühn & Gallinat, 2015) and media multitasking (Loh & Kanai, 2014) are associated with reduced grey matter in prefrontal areas involved in attention regulation, such as the right frontal pole and anterior cingulate cortex. Individuals who frequently adopt multitasking on smartphones, rapidly alternating between different activities, show greater exposure to distraction and present lower results in cognitive flexibility tests, when compared to users who avoid multitasking (Ophir et al., 2009). The results of a study by Uncapher et al. (2017) suggest that those who practice intense multitasking with digital media are more susceptible to interference caused by irrelevant external stimuli or internal representations in their memory system, which results in worse performance in tests of task switching ability.

However, there are data in the literature that support the positive effects of multitasking, particularly in adulthood.

Anguera et al. (2013) found a significant improvement in multitasking abilities in participants aged 60-85 years who received a four-week training with specific video games. The results, which were superior to those of the non-trained group of 20-year-olds, were maintained for six months after the end of the training and produced collateral benefits in working memory, divided attention and sustained attention. In addition, a recent review by Firth et al. (2024) found that certain multitasking activities, such as listening to podcasts during a manual task, can promote a sense of productivity (Spjeldnæs & Karlsen, 2024; Perks & Turner, 2019).

The impact on attention

A growing amount of scientific evidence underlines the impact of the increasing use of social media on attentional capacity. This has led researchers to suspect a possible correlation between the increase in digital media use among young people and the rise in ADHD diagnoses.
In line with this claim, several studies have shown an association between excessive Internet use and attention problems. A study by Ra et al. (2018) showed that students who did not use digital media at baseline at high frequency had a lower rate of ADHD symptoms at follow-ups than students who used media frequently for different activities, with symptoms increasing as high-frequency activities increased. Long-term media use and irregular sleep-wake cycle routines may promote the onset of symptoms associated with ADHD (Thoma et al., 2020). A meta-analysis (Nikkelen et al., 2014) found a significant positive correlation between television or video game use and behaviours associated with ADHD, such as attention problems and impulsivity. Furthermore, longitudinal studies (Gentile et al., 2012; Landhuis et al., 2007; Swing et al., 2010) have highlighted that early exposure to these media could contribute to the onset of attentional deficits at a later age. The recent review by Firth et al. (2024) found that behavioural and qualitative studies reveal that smartphone and social media use can influence attention. For example, the level of distraction of university students, measured as procrastination, appears to be related more to the automatic nature of social media interaction than to frequency of use (Aalbers et al., 2022). Users often find themselves in a state of 'unconscious scrolling', with a loss of a sense of time and difficulty in focusing on structured tasks (Arness & Ollis, 2023). Neuroimaging studies (Lee et al., 2021) have also shown deficits in top-down attentional control, with lower functional connectivity between the dorsal attentional dorsal cortex and the dorsolateral prefrontal cortex (DLPFC) in users with excessive social media use.
The study by Uttal et al. (2013) exploring the impact of video games on attention and spatial skills showed instead that video games can be used to improve these skills, with players that perform better on tasks requiring attention and spatial skills. However, the success of the intervention depends on personal factors, the type of video game used, and the duration and frequency of gaming sessions. Although there are associations between attention difficulties in youth and Internet use, there is not enough evidence to show that reducing social media use improves attention (Firth et al., 2024).

Effects on attention and memory components

Memory is also a cognitive process that can be affected by the use of technology. Several studies have found that the use of the Internet for research purposes can decrease the activation of brain areas involved in working memory (Dong & Potenza, 2015; Dong & Potenza, 2016).
Moreover, as the global network acts as a 'superstimulus for transactive memory' (Sparrow, 2011; Ward et al., 2013; Wegner & Ward, 2013), it encourages an inordinate use of external information storage sources, which are always available and easily accessible. In support of this, empirical evidence suggests that the use of the Internet for search and information-acquisition activities not only accelerates these processes, but also changes the brain activation patterns associated with the storage and retrieval of long-term memory information (Sparrow et al., 2011; Dong & Potenza, 2015).

There is, however, research showing positive effects of technologies on memory tasks (Soares et al., 2021). Kühn et al. (2014) conducted a randomised experiment on young adults using the video game Super Mario 64, with sessions of 30 minutes per day for two months. Compared to a control group, the experimental group showed a significant increase in grey matter in brain areas involved in working memory, spatial navigation and strategic planning. Similarly, Mosaila et al. (2017) analysed the performance of subjects with different frequency of video game use through fMRI scans. The results indicate that frequent gamers show more efficient regulation of frontal and parietal brain areas, with better performance in working memory in response to task difficulty. The Internet can also be a valuable resource for the elderly population, who experience a physiological cognitive decline with advancing age, allowing them to access useful information to maintain their autonomy for as long as possible (Small et al., 2020).

Discussion

The results of the present narrative review highlight a complex and ambivalent impact of digital technology use on cognitive functions, particularly attention, memory, and multitasking. The increasing use of digital devices, especially among adolescents, is associated with structural and functional changes in the brain, which may be reflected in both potential benefits and negative effects, depending on frequency, mode of use, and individual user characteristics (Firth et al, 2019; Paulus et al., 2019; Small et al., 2020).

In regard to the attention topic, numerous studies suggest a correlation between excessive social media use and attentional difficulties, with an increased susceptibility to distraction and a decreased ability to sustained concentration (Ra et al., 2018; Nikkelen et al., 2014; Aalbers et al., 2022). These alterations appear to be mediated by changes in functional connectivity between cortical areas implicated in top-down control of attention, such as the DLPFC (Lee et al., 2021). However, some evidence suggests that certain types of video games may train attentional selectivity and improve rapid stimulus processing abilities, especially in adult or elderly subjects (Uttal et al., 2013; Anguera et al., 2013).

Memory also appears to be heterogeneously affected. While using the Internet as an external repository of information (transactive memory) may reduce long-term memory consolidation and activation of specific cortical areas (Sparrow et al., 2011; Ward, 2013; Dong & Potenza, 2015, 2016), digital tools and video games appear to improve working memory and strategic skills in controlled contexts (Kühn et al., 2014; Moisala et al., 2017; Soares et al., 2021).

Regarding multitasking, the data predominantly show a negative impact on cognitive efficiency. Individuals who frequently practice digital multitasking exhibit increased distractibility, decreased cognitive flexibility, and reduced ability to filter irrelevant stimuli (Loh & Kanai, 2014; Ophir et al., 2009; Uncapher et al., 2017). However, in some contexts and for some age groups, such as the elderly, video game-mediated multitasking can stimulate divided attention and working memory, with positive effects maintained over time (Anguera et al., 2013; Firth et al., 2024).

Overall, the use of digital technology acts as a neurocognitive modulator, and the effect depends on the type of stimulation, duration of exposure, and characteristics of the individual. The data support the hypothesis of a bidirectional relationship, in which technology can both improve and impair cognitive function. Therefore, it is crucial to promote conscious and critical use of digital tools, including through educational interventions and preventive strategies (Firth et al., 2024; Haddock et al., 2022).

Conclusions

Nowadays, the way we relate to the world is increasingly influenced by the presence of digital technologies, which have become part of the lives of generations of all ages, especially the youngest. Smartphones, social media and digital platforms have an increasing impact on cognitive functioning. Recent literature suggests that the overuse of digital technologies involves both opportunities and challenges. Although there are worries about the impact on well-being and cognitive abilities, technology also offers innovative tools for learning, entertainment and improving quality of life. However, the balance between benefits and risks is highly dependent on context, usage patterns and individual characteristics.

Based on these considerations, it is essential to promote an informed and critical use of technology that maximises benefits while minimising potential negative effects. Further research is needed to better understand the long-term impact of digital technologies and to develop educational, social and health strategies that help to effectively manage this transition to an increasingly connected society.

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Author's Contributions

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