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Vinodhkumar Ramalingam,
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Kesong Hu,
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Tianxiao Yang,
Chinese Academy of Sciences (CAS), China

*CORRESPONDENCE

Mathura Shanmugasundaram
✉ mathura@alumni.harvard.edu

†These authors have contributed equally to this work

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The impact of digital technology, social media, and artificial intelligence on cognitive functions: a review

Mathura Shanmugasundaram^{1*†} and Arunkumar Tamarasu^{2†}

¹Harvard Medical School, Harvard University, Boston, MA, United States, ²Independent Researcher, Boston, MA, United States

In our modern society, digital devices, social media platforms, and artificial intelligence (AI) tools have become integral components of our daily lives, profoundly intertwined with our daily activities. These technologies have undoubtedly brought convenience, connectivity, and speed, making our lives easier and more efficient. However, their influence on our brain function and cognitive abilities cannot be ignored. This review aims to explore both the positive and negative impacts of these technologies on crucial cognitive functions, including attention, memory, addiction, novelty-seeking and perception, decision-making, and critical thinking, as well as learning abilities. The review also discusses the differential influence of digital technology across different age groups and the unique challenges and benefits experienced by children, adolescents, adults, and the elderly. Strategies to maximize the benefits of the digital world while mitigating its potential drawbacks are also discussed. This review aims to provide a comprehensive overview of the intricate relationship between humans and technology. It underscores the need for further research in this rapidly evolving field and the importance of informed decision-making regarding our digital engagement to support optimal cognitive function and wellbeing in the digital era.

KEYWORDS

cognitive function and development, digital technology, neuroscience, digital and social media, screen time, brain development, ChatGPT, artificial intelligence (AI)

1 Introduction

In recent years, the proliferation of digital tools, such as smartphones, social media platforms, and artificial intelligence technologies, has ushered in a significant paradigm shift in our interaction with information. These tools have undeniably enriched our lives by offering unparalleled convenience, connectivity, speed, and efficiency. The advent of smartphones, for instance, has made access to information and communication incredibly convenient, enabling us to effortlessly retrieve facts, connect with others, and accomplish various tasks with a simple tap on a screen. Similarly, social media platforms have revolutionized the way we interact and share information, facilitating global connectivity and nurturing communities. Furthermore, artificial intelligence (AI) tools have automated numerous processes, streamlined workflows and enhanced productivity.

The impact of digital tools on brain function and cognition is a complex and intricate area of study that has prompted extensive research by researchers and experts. As we strive to comprehend the effects of technology on our cognitive abilities, it has become increasingly challenging to differentiate between mere correlation and actual causation due to our constant reliance on and utilization of digital tools.

2 Attention

Extensive research in cognitive psychology has demonstrated that humans possess a finite capacity for sustained attention and can only maintain focus on a specific task or stimulus for a limited period of time. This capacity is not fixed and varies depending on several factors such as the nature of the task itself and individual drivers like interest, motivation and personal experience (Chun et al., 2011; Oberauer, 2019). However, the rapid rise of digital tools like smartphones, social media, and other forms of technology has brought about new challenges in maintaining sustained focus and have made it easier than ever to be constantly and perpetually distracted. Smartphones, in particular, have become pervasive in modern society, and excessive smartphone use is associated with poorer attentional control (De-Sola Gutiérrez et al., 2016). Social media platforms, such as Facebook, Instagram, Snapchat, Tiktok, Threads, and Twitter, have also become major sources of distraction. The constant notifications, updates, and scrolling feeds can draw individuals' attention away from important tasks and create a state of perpetual partial attention. A study by Kross et al. (2013) revealed that passive use of Facebook predicted decreased wellbeing and increased feelings of distraction and inattention.

One of the most significant challenges the digital world poses for attention is attentional overload. Attentional overload occurs when the demands of the environment exceed the capacity of an individual's attentional resources. The digital world presents a wide range of stimuli, including alerts, personalized notifications, social media updates, emails, tweets, calendar reminders, texts, and news feeds, all of which compete for an individual's attention.

The phenomenon of "continuous partial attention" is a symptom of attentional overload in the digital world (Stone, 2007). Continuous partial attention refers to the state of continuously dividing and shifting one's attention across multiple tasks or stimuli without fully immersing oneself and only partially engaging in any one of them. This practice can lead to a superficial understanding of information and a reduced ability to concentrate on any one task or piece of information. We have indeed transitioned now from the information age to the age of interruption (Firth et al., 2019). The irony of our century is the ease with which we can find resources to read at any time and place, but at the expense of having constant distractions interrupting our focus and attention. This can be characterized by the constant urge to stay connected and keep up with various sources of information, often driven by the "fear of missing out" or FOMO (Przybylski et al., 2013). Continuous partial attention is closely related to the influence of digital technologies and the rise of digital tools have amplified the prevalence of such phenomenon (Oulasvirta et al., 2012).

The consequences of continuous partial attention can be detrimental to cognitive performance and overall wellbeing and can lead to reduced productivity, decreased memory retention, and increased stress levels. In addition to continuous partial attention, the digital world can also contribute to attentional overload through multitasking. Multitasking involves the simultaneous performance of two or more tasks, which can reduce the efficiency and accuracy of attentional processing (Rosen et al., 2013a). The ability to multitask may lead to a sense of productivity, but it can also lead to a decreased ability to focus and retain information.

Moreover, the constant urge to stay connected and respond to notifications can lead to distracted real-life in person conversations and create a diminished sense of presence even in face-to-face interactions thereby hindering deep engagement and empathy in interpersonal relationships (Turkle, 2011).

2.1 Factors contributing to attentional overload in the digital world

Several factors contribute to attentional overload in the digital world. One of the most significant factors is the intentional design of digital devices and platforms. Many digital devices and platforms are designed specifically to be highly engaging, using features such as notifications, alerts, personalized content, reminders and gamification to capture, retain and maintain users' attention (Dabbish et al., 2011). These design features can be effective in promoting engagement but can also contribute to attentional overload. For example, the "infinite scroll" feature and autoplaying of videos on social media platforms, where content continuously loads as users scroll down, encourages endless browsing and can lead to attentional overload. Similarly, the use of bright colors, animations, and interactive elements in application designs aim to stimulate users and maintain their engagement.

Another factor that contributes to attentional overload in the digital world is the sheer volume of information available. The internet provides access to an endless supply of information, and social media platforms generate an ever-increasing stream of content. The abundance of information can create a sense of urgency to stay connected and informed, leading to continuous partial attention and multitasking. Research shows that notifications and alerts from digital tools can disrupt attention and impair cognitive performance (Iqbal and Horvitz, 2007). An average person checks their phone at least 85 times per day (Andrews et al., 2015) and has little awareness of the frequency with which they check their phone and rapid mobile phone interactions and "checking behaviors" are increasingly becoming more and more habitual.

Continuous distractions during the workday can have significant effects on perceived workload and stress levels. When individuals are constantly interrupted or diverted from their tasks, their ability to concentrate and maintain productivity is compromised. This can lead to an increased perception of workload as tasks take longer to complete due to the interruptions. Individuals tend to compensate for the distractions by working harder to make up for lost time or to regain focus on their tasks and this increased effort results in higher frustration and stress levels (Mark et al., 2008). Another study explored the effects of interruptions on employees' wellbeing and job satisfaction (Trogakos et al., 2008) and reported that frequent interruptions disrupted workflow, leading to increased psychological strain and decreased job satisfaction. The researchers suggested that interruptions not only increased perceived workload but also contributed to a sense of time pressure and reduced work engagement. These findings align with the concept of cognitive load theory, which suggests that cognitive resources are limited,

and multitasking or continuous distractions can overwhelm these resources, leading to increased perceived workload and stress (Sweller, 2011).

The constant use of digital tools can impact the brain's ability to focus and sustain attention. Heavy multitaskers performed worse on a task that required sustained attention than those who were light multitaskers (Ophir et al., 2009). Children who used digital tools for more than 2 h per day had lower scores on cognitive tests than those who used them less (Firth et al., 2019). Students could only focus for 6 min in the presence of a technological distractor such as texting, social media updates, and digital task-switching on other windows (Rosen et al., 2013a). Studies show that students who were distracted by text messages during lectures performed worse on comprehension tests compared to those who were not distracted (Rosen et al., 2011). In addition, although video games can improve certain aspects of attention, such as selective attention and visual-spatial processing, excessive use may also lead to attentional difficulties, such as reduced sustained attention and increased distractibility, particularly in children (Bavelier et al., 2010). Higher levels of digital media use, particularly multitasking with multiple devices, have been associated with lower academic achievement (Junco and Cotten, 2012).

Several studies have also found an association between extensive use of digital devices and symptoms of attention deficit hyperactivity disorder (ADHD). While it is important to note that correlation does not imply causation, the research suggests a potential link between digital device use and ADHD symptoms. Higher levels of screen time, including television viewing, video gaming, and computer use, are associated with an increased likelihood of experiencing ADHD symptoms (Nikkelen et al., 2014). The constant stimulation and rapid shifts in attention demanded by digital media may contribute to attentional difficulties resembling ADHD symptoms. A reciprocal relationship, with higher digital media use predicting increased ADHD symptoms, and higher ADHD symptoms predicting increased digital has also been reported (Sibley and Cox, 2018; Adelantado-Renau et al., 2019) suggesting that excessive digital media use and ADHD symptoms may reinforce each other in a complex manner. Correlations have also been observed between screen media use and ADHD symptoms in children and adolescents (Ra et al., 2020). While these studies provide insights into the potential association between digital device use and ADHD symptoms, it is important to consider that the nature of this association is still not fully understood and further research is required to establish the directionality and underlying mechanisms. Other factors, such as pre-existing tendencies or underlying vulnerabilities, may influence both digital device use and the manifestation of such symptoms.

Individuals who frequently engage in media multitasking (e.g., using multiple digital devices simultaneously) have reduced gray matter density in the anterior cingulate cortex, a brain region associated with cognitive and emotional regulation which suggests that digital media use may have a negative impact on brain structure and function (Loh and Kanai, 2014).

3 Memory

Digital dementia is a term used to describe the decline in cognitive abilities caused by excessive use of digital technology

(Spitzer, 2012). This phenomenon has become a growing concern, particularly among younger generations, who are more likely to be connected to digital devices than ever before. Studies have shown that digital dementia can lead to a range of cognitive impairments, including memory loss, attention deficit, reduced ability to communicate, and impaired decision-making abilities (Manwell et al., 2022).

The overreliance on digital technology is one of the primary causes of digital dementia. When individuals rely on digital devices to store information, they are less likely to remember it over the long term, leading to memory loss. Studies indicate that overreliance on technology for even simple tasks can lead to decreased performance in memory recall. Studies suggest that people have become increasingly reliant on search engines like Google to access information, rather than remembering the information itself. For example, a simple action such as using smartphones or "Google calendar" to remind of appointments, deadlines and essential tasks enable one to offload this task from our memory to our "external memory": the internet (Sparrow et al., 2011). Increased usage of GPS has also been linked to steeper declines in hippocampal-dependent spatial memory (Dahmani and Bohbot, 2020). In addition, even taking digital photographs seem to decrease recall accuracy for details of images (Henkel, 2014).

Furthermore, the constant barrage of information and distractions that come with digital technology can overload the brain, making it difficult to process information and retain it (Lin et al., 2015). Individuals who use smartphones more frequently also have shorter attention spans than those who used them less often (Lui and Wong, 2012).

Research has also shown that excessive use of digital technology can alter brain structure and function, leading to a range of cognitive impairments. Internet addiction was associated with reduced gray matter density in the brain's frontal cortex, which is responsible for decision-making and impulse control (Chen et al., 2023). Smartphone addiction has also been associated with reduced activity in the prefrontal cortex, which is responsible for decision-making and impulse control (Lin et al., 2015).

In one study, participants were divided into three groups: one group was allowed to use their phones during a lecture, one group was asked to place their phones face down on the desk, and one group was asked to leave their phones outside the room. The results showed that the group that used their phones during the lecture had the lowest recall of the lecture material (Thornton et al., 2014). In fact, just the mere presence of a cell phone alone and the digital accessibility it represents itself was found to be distracting. Similarly, the use of smartphones during a memory task can decrease accuracy. In another study, participants who used their phone during the task to remember words had lower accuracy compared to those who did not use their phone (Ward et al., 2017).

The constant stream of information from digital tools can also impair our ability to retain information over time. Cain et al. (2016) reported an association between increased media multitasking and poorer working memory performance and lower academic outcomes. In addition, college students with increased levels of Facebook usage demonstrated worse outcomes on cognitive tasks such as free recall activities (Frein et al., 2013). Participants who reported using Facebook more frequently also had lower gray

matter density in the anterior cingulate cortex, a brain region involved in memory and emotional regulation (Kanai et al., 2012).

There is also evidence to suggest that the use of digital tools can impact brain function in other ways. For example, a study found that heavy social media use was associated with decreased gray matter volume in the amygdala, a brain region involved in emotion regulation (Montag et al., 2017). Another study found that participants who were heavy users of video games had smaller gray matter volume in the hippocampus, a brain region involved in spatial memory (Kühn and Gallinat, 2014). Excessive use of digital devices has also been linked to cognitive impairments resembling those seen in dementia. Interestingly, these effects are increasingly observed in younger adults who are not typically expected to experience age-related neurodegeneration associated with old age (Manwell et al., 2022).

Despite these findings, it's important to note that not all digital tools are created equal, and some may even have positive effects on memory and cognitive function. Playing action video games improved memory and attention in older adults (Anguera et al., 2013). Similarly, Social media use can also influence self-referential processing, where individuals reflect on their own traits and qualities. A study by He et al. (2017) found that the frequent use of WeChat, a popular social media application, was positively correlated with gray matter volume in the precuneus, suggesting that heavy social media use may be linked to changes in brain structure in regions associated with self-referential processing.

Regardless it remains important to mitigate the negative effects of digital dementia. Several potential solutions have been proposed and one of the most effective is to limit digital technology use, particularly among younger generations. This could involve setting limits on screen time and encouraging activities that stimulate the brain, such as reading, exercising, and socializing with friends and family. Another solution is to incorporate brain training exercises into daily routines, such as memory games and puzzles, to help maintain cognitive abilities.

4 Addiction

Addiction is becoming a growing concern due to the widespread use of technology. Addiction can lead to changes in cognitive function, impacting one's ability to think critically, remember important details, and make sound decisions. The instant gratification and constant stimulation provided by technology can create a compulsive need for more leading to addiction.

Internet addiction has been associated with reduced attention span and working memory as well as impaired decision-making, specifically in the area of risk assessment (Dong et al., 2013). Smartphone addiction is associated with decreased cognitive function (Lee et al., 2017) and deficits in attention and executive function such as inhibition and working memory (Lin et al., 2015).

Moreover, addiction in the digital world can also impact social cognition, which refers to the ability to understand and interact with others. Internet addiction is associated with decreased empathy, which is an important component of social cognition (Tao et al., 2010). Excessive use of social networking sites is

associated with decreased social skills and a decreased ability to recognize facial emotions (Blachnio et al., 2016). In addition, symptoms of digital technology and internet addiction can include withdrawal symptoms when the internet is inaccessible (Kuss and Griffiths, 2012). Some users may also develop an emotional attachment to online friends and digital activities which can contribute to their addictive desire to maintain their online presence (Young, 1998). People with internet addiction show impairment of white matter fibers in the brain connecting regions involved in generations of emotions and cognitive control as well (Zhou et al., 2011). Furthermore, frequent exposure to emotionally arousing content, such as social media posts or online news, can disrupt emotional regulation processes and contribute to heightened stress, anxiety, and depressive symptoms. Excessive social media use is associated with increased emotional reactivity and decreased emotional recovery, indicating difficulties in regulating emotional responses (Puukko et al., 2020).

Addictive behaviors have been tied to changes in the brain's reward system. The brain's reward system plays a crucial role in regulating motivation, decision-making, and self-control. Digital technology, with its array of engaging content and online activities, can hijack this reward system, leading to potential challenges in self-control and psychological regulation. Research has shown that excessive digital use, particularly related to activities such as social media and gaming, can trigger addictive behaviors by activating the brain's reward circuitry. This activation is mediated by the release of dopamine, a neurotransmitter associated with pleasure and reward (Báez-Mendoza and Schultz, 2013).

Excessive online gaming has been linked to alterations in the reward system, including increased activation in reward-related brain regions (Kuss et al., 2014). Studies have demonstrated that heavy digital media use is associated with lower levels of reward self-control. Individuals who frequently engage in media multitasking exhibited reduced reward self-control, leading to impulsive decision-making and decreased academic performance (Wilmer et al., 2017). Similarly, a negative correlation between social media use and reward self-control has been observed, indicating that higher levels of social media engagement were associated with weaker self-control abilities (Meshi et al., 2019).

In addition, the ventral striatum, a key part of the reward system, has been associated with compulsive internet use (Kuss and Griffiths, 2012). Brain responses observed in individuals with internet gaming disorder when they were winning or losing money found increased activity in the ventral striatum when these individuals anticipated winning, which may reflect an increased sensitivity to potential rewards (Dong et al., 2012).

Research using neuroimaging techniques has shown that individuals with problematic internet use exhibit structural and functional changes in the prefrontal cortex (PFC) and the anterior cingulate cortex (ACC). These areas of the brain are critical for higher cognitive functions such as decision-making, impulse control, and emotion regulation. Adolescents with internet addiction exhibited decreased gray matter density in several brain areas, including the dorsolateral prefrontal cortex (DLPFC) and the rostral ACC (Yuan et al., 2011). The DLPFC is implicated in executive functions such as decision making and cognitive control, whereas the ACC is involved in emotion processing and

regulation. Functional changes in these brain areas have also been reported. An fMRI study observed that individuals with internet gaming addiction showed heightened activation in the PFC during a decision-making task, which may suggest impaired cognitive control and decision-making ability (Dong et al., 2012). Similarly, individuals with internet gaming disorder exhibited impaired function in the ACC during a color-word Stroop task, which assesses cognitive control and response inhibition (Dong et al., 2013). Apart from structural and functional changes, alterations in the functional connectivity between these brain regions have also been observed. Individuals with internet gaming addiction showed altered resting-state functional connectivity between several regions, including the ACC and the PFC which might reflect a dysfunction in the neural network involving these areas, which is implicated in cognitive control and emotional regulation (Hong et al., 2013).

Digital technology's impact on the brain extends beyond addiction and the reward system and can affect broader psychological regulation processes. Excessive digital use can disrupt the brain's reward system, impair reward self-control, and affect broader psychological regulation processes. Understanding these dynamics is crucial for promoting healthy digital habits and maintaining psychological wellbeing. To foster better reward self-control and psychological regulation, interventions such as digital detoxes, mindfulness practices, and promoting offline activities are recommended. Further research is needed to delve deeper into the specific mechanisms underlying the impact of digital technology on reward self-control and psychological regulation and to develop effective strategies for mitigating potential negative consequences.

5 Novelty seeking and perception

Novelty seeking is a fundamental aspect of cognition associated with exploration, curiosity, and the desire for new experiences (Kashdan et al., 2004). Digital technology, with its virtually endless availability of new content, has dramatically reshaped novelty seeking behaviors.

The internet, social media, and various digital platforms introduce an abundance of novel stimuli, thus reinforcing novelty-seeking behavior (Achterberg et al., 2022). On one hand, this fosters curiosity and broadens intellectual horizons. However, the overload of novel information can lead to cognitive fatigue and a skewed perception of reality due to the selection and amplification of certain types of content (Eppler and Mengis, 2004). Social media platforms can create echo chambers and filter bubbles acting as altered perceptual filters. These personalized information ecosystems selectively present information that aligns with users' preexisting beliefs and preferences, potentially distorting perception and reinforcing biases (Pariser, 2011). The vast offerings of the digital world offer immersive and interactive experiences through visual and audiovisual content. Virtual reality, augmented reality, and multimedia applications can enhance perception by providing realistic and engaging learning experiences (Boucsein, 2019) however they also provide uniquely immersive experiences, altering our perception of physical space (Bohil et al., 2011). These technologies enhance experiential learning but also present

challenges, such as disorientation and a blurred distinction between the virtual and physical world.

In addition to influencing the width of perception, digital use can exponentially aid in increasing exposure and accessibility to diverse and constantly changing stimuli which can contribute to increased novelty seeking behavior. Studies have shown that individuals who frequently use digital media tend to seek out novel and stimulating experiences (Przybylski et al., 2013). A study by Carrier et al. (2015) found that heavy internet users were more likely to display signs of impulsivity, suggesting that the instant feedback provided by the online environment might promote a need for instant gratification. Many digital platforms also often incorporate gamification elements, rewards, and personalized recommendations and such features act to reinforce novelty seeking behaviors by providing immediate feedback and tailored content based on users' preferences and past engagement (Hamari et al., 2014).

It is undeniable that digital technologies can provide opportunities for discovery, exploration, and learning through exposure to new and diverse information and help to foster creativity, curiosity, and adaptability, which are valuable traits in the modern world (Nussbaum et al., 2021). However, it is still critical to note that excessive novelty seeking and underestimating personalization of content presented in the digital realm may lead to a constant search for new stimuli, potentially detracting from focused and sustained learning. It can also contribute to information overload, reduced depth of understanding, and difficulties in maintaining attention and self-regulation (Rosen et al., 2013b).

Furthermore, in the realm of social perception, digital technology significantly influences how we perceive and interact with others. Online communications can amplify misunderstandings due to the lack of non-verbal cues, altering the perception of others' intentions and emotions. Digital communication platforms often give rise to an "egocentric bias" where individuals tend to overestimate their ability to communicate attitudes, emotions, and sarcasm through digital means and can potentially lead to inaccurate perceptions of other's intentions and emotions (Kruger et al., 2005). In addition, the comparative nature of social media can lead to a skewed and biased perception of others' lives, often perceived as more successful or happier, leading to a phenomenon known as "Facebook envy" (Krasnova et al., 2013). This altered perception can have significant impacts on mental health, leading to feelings of inadequacy and decreased overall satisfaction in life. Personalized algorithms on social media platforms can result in focused content, where users are exposed primarily to topics and opinions that align with their own (Bakshy et al., 2015) which can lead to a narrow perception of social reality and polarization in opinions and beliefs.

Perception of self in the digital sphere is also an interesting aspect. Studies have found that individuals tend to curate their online avatars and identities positively and attractively. This is partly due to the "hyperpersonal effect" (Walther, 1996), where people utilize the asynchronous nature of digital communication to selectively self-present, leading to an idealized version of oneself. This self-presentation can significantly influence how we perceive

others and ourselves, often creating a gap between reality and digital identity.

While the digital era has enhanced our spatial perception through immersive technologies and enriched our social interactions by bridging geographical gaps, it has also introduced complications. Misunderstandings due to the absence of non-verbal cues, potential distortions in self and others' perception due to online identity curation, and the formation of echo chambers and filter bubbles are amongst the challenges that require careful consideration. As we embrace the next digital evolution, it is essential to strike a balance. We must leverage the benefits of digital technology in promoting novelty seeking and enriching perception, while also being mindful of, and mitigating, the potential drawbacks. This necessitates ongoing research to understand these effects better and to devise strategies for optimal digital engagement. Ultimately, the key lies in utilizing digital technology as a tool for cognitive enhancement, enriching our novelty seeking and perceptual experiences, rather than letting it become a source of cognitive distress. This will enable us to harness the power of digital technology for cognitive wellbeing and development in our increasingly digitized world.

6 Decision-making

Digital technology has vastly influenced the cognitive process of decision making, affecting how we gather, process, and evaluate information to make choices. These influences have both empowering and potentially disruptive implications.

The rise of digital technology has significantly enhanced our ability to access a wealth of information. Increasing internet usage has led to more informed decision making due to a broader range of accessible data. However, the overwhelming volume of information available can lead to information overload, complicating the decision-making process and potentially causing decision paralysis (Eppler and Mengis, 2004). Cognitive overload occurs when the brain is exposed to an excessive amount of information or stimuli, which can overwhelm the brain's capacity to process it all (Sweller, 1994). In one study, participants who spent more time on social networking sites showed a higher level of cognitive overload, leading to a decrease in their ability to make decisions (Junco and Cotten, 2012). This finding highlights the importance of limiting digital use to avoid cognitive overload, which can impair decision-making skills.

Algorithm-driven recommendations have become a cornerstone of digital platforms, helping users make choices in various contexts, from online shopping to entertainment. While these algorithms can streamline decision making by providing tailored options (Li et al., 2019), they can also lead to cognitive biases. These biases, in turn, can reduce exposure to diverse perspectives, leading to sub-optimal decisions and perpetuating confirmation bias (Pariser, 2011). Social media platforms can also significantly influence decision making by providing immediate access to peer opinions and reviews, which have been shown to greatly impact consumer decision making (Hajli, 2014). However, they also lead to the risk of groupthink, where peer pressure can impact individual decision-making processes and outcomes (Janis, 1972). Face-to-face social interactions are important for developing

social skills and practicing decision-making in real-life situations. Social media use has been negatively associated with face-to-face social interactions, which can impact the development of social skills and decision-making abilities as well (Pontes et al., 2018).

Digital distractions are another aspect of technology that can impact decision making. Continuous digital distractions might reduce the cognitive capacity for careful deliberation, leading to more impulsive decisions (Duke and Montag, 2017). Participants who were interrupted by a text message while performing a decision-making task showed a decrease in the quality of their decisions, highlighting the impact of digital distractions on decision-making skills (Mark et al., 2017). Furthermore, excessive use of digital technology, particularly smartphones, can induce cognitive offloading, which refers to the reliance on external tools for cognitive functions, including decision making, potentially reducing our cognitive capabilities (Ward et al., 2017).

Digital use can impair decision-making skills by causing addiction-like behavior. Digital devices and technology can be highly addictive, leading to excessive use and a decrease in self-control. People who used their phones more frequently had a harder time delaying gratification and were more likely to make impulsive decisions (Rosen et al., 2013b). Excessive digital use can lead to addiction-like behavior and impaired decision-making skills (Billieux et al., 2015).

In addition, digital use can lead to a decrease in critical thinking skills, which can further impair decision-making abilities. Participants who were exposed to social media posts with misleading information showed a decrease in their ability to critically evaluate the information presented, leading to impaired decision-making skills (Aïmeur et al., 2023). Furthermore, video game addiction was associated with lower self-control and impulsive decision-making (Gentile et al., 2012). These findings suggest that excessive digital use can impair decision-making skills by decreasing self-control and increasing impulsivity.

To mitigate the impact of digital use on decision-making skills, it is important to develop critical thinking skills and establish healthy digital habits. Individuals who engaged in critical thinking while using social media were less likely to be influenced by misleading information, highlighting the importance of developing critical thinking skills in the digital age (Machete and Turpin, 2020). Setting boundaries on screen time and taking breaks from digital devices can help reduce cognitive overload and increase self-control. Additionally, engaging in face-to-face social interactions can help develop social skills and improve decision-making abilities.

7 Critical thinking and learning abilities

Constant distractions of the digital world can lead to a decreased ability to concentrate and think deeply (Carr, 2020). Students who spent more time on Facebook had lower GPAs than those who spent less time on the social networking site (Junco and Cotten, 2012). The researchers concluded that excessive use of social media can interfere with academic performance. Similarly, students who used multiple digital devices simultaneously had lower comprehension scores compared to those who used only

one device (Rosen et al., 2013a). The internet is changing the way we think and process information, leading to shallower and more distracted thinking.

Digital devices have also been linked to a decrease in attention span, which can impact learning. Participants who used smartphones more frequently had shorter attention spans than those who used them less often (Lui and Wong, 2012). In addition, excessive digital media use is associated with poorer cognitive control, including attention and inhibitory control (Fossati et al., 2018). Furthermore, digital devices have been linked to disrupted sleep patterns, which can also affect learning. Adolescents who used electronic devices at bedtime had increased sleep problems and daytime sleepiness, which can impair cognitive function and academic performance (Hysing et al., 2015). Research has also shown that greater screen time in children is associated with lower cortical thickness, particularly in areas associated with language and literacy skills (Paulus et al., 2019).

There are several possible mechanisms through which digital device use can impair learning brain function. One mechanism is through the effects of blue light emitted by digital screens. Blue light has been shown to suppress melatonin production, which can disrupt the sleep-wake cycle and impair cognitive function (Cajochen et al., 2011). Another possible mechanism is through the effects of digital media on brain structure and function. Lin et al. (2015) found that prolonged internet use was associated with reduced gray matter density in the anterior cingulate cortex, which is involved in cognitive and emotional processing. Excessive video gaming has also been associated with reduced gray matter volume in the striatum, which is involved in reward processing and impulse control (Kühn and Gallinat, 2014).

7.1 Artificial intelligence

Artificial intelligence (AI) is progressively intertwined with human cognition, impacting how we think, learn, make decisions, and interact with the world. AI tools can aid in cognitive tasks, enhancing human capabilities. AI is increasingly used in decision-making processes. For example, AI algorithms can analyze vast data sets to detect patterns and trends, something human cognitive function may find overwhelming due to inherent limitations (Gunning et al., 2019). These algorithms can help humans make data-driven decisions and offer recommendations. AI-driven tools like IBM's Watson have been used in healthcare to help physicians make more informed decisions by providing valuable data-driven insights (Ferrucci et al., 2010). However, as with cognitive offloading, there is a potential risk that over-reliance on AI for decision-making could diminish human capacity for critical thinking (Rudin, 2019). AI-based GPS navigation systems such as "Google Maps" or "Waze" not only help us navigate through unfamiliar environments but may also affect brain areas related to spatial cognition and navigation skills (Iaria et al., 2009).

AI also has profound implications for learning processes. Adaptive learning platforms like Carnegie Learning provide personalized learning experiences tailored to individual needs, which can enhance learning outcomes (Graesser et al., 2018). AI can identify a learner's predominant learning style and provide

content accordingly. If a student is a visual learner, AI may deliver content through visual aids, animations, or videos and may emphasize textual materials if the student is more inclined toward reading or writing. AI can also adapt to each learner's own pace and style, providing personalized content ensuring engagement and better understanding and retention of materials (Zawacki-Richter et al., 2019). In addition, AI is capable of providing real-time feedback, which can enhance learning by immediately addressing misconceptions and reinforcing concepts (Hattie and Timperley, 2007; Shute, 2008). Interactive AI-powered toys and educational tools can provide personalized learning experiences that can enhance cognitive development (Chowdhury et al., 2020). However, there are concerns about children's over-reliance on AI tools for problem-solving and decision-making. Children need opportunities to tackle challenges and learn skills to solve problems independently, a process that can be circumvented by AI, potentially affecting the development of these skills (Chiong and Shuler, 2010). However, the role of AI in learning also raises questions about the nature of learning and the value of human teachers.

AI has implications for social cognition as well. Interactions with social robots or AI chatbots can influence our perceptions, attitudes, and social interactions (Broadbent, 2017). AI tools like Woebot, are being used to provide mental health support. These bots can provide cognitive-behavioral therapy-based interventions, thereby potentially improving mental wellbeing and making therapy more accessible (Fitzpatrick et al., 2017; Vaidyam et al., 2019). This suggests a possible influence on brain areas associated with emotional regulation, like the prefrontal cortex and the amygdala. Although these findings are promising, it is important to note that AI tools are best used as a supplement to, rather than a replacement for, traditional therapy. Chatbots lack the ability to understand and respond to complex human emotions (Clarke and Yarborough, 2013). Digital applications such as "Headspace" and "Calm" guide users through meditation practices and can help in reducing mental stress, improving attention and focus and enhance cognitive resilience (Bostock et al., 2019).

It is also important to recognize AI tools such as ChatGPT, that has been designed to process natural language and generate text in response to various queries. They can help users explore different and new perspectives, supporting informed decision making (Carr, 2020). Language model tools can also help language acquisition and development and act as a resource for learning new language or practicing conversation in a non-judgmental environment (Hill et al., 2015). Applications such as "Duolingo" utilize AI to adapt to a user's learning style and pace, presenting new words and exercises based on previous performance. Personalization in these type of softwares can help enhance language learning efficiencies (Duolingo, 2020). Such applications can also be used for language proficiency tests (Settles et al., 2020). Notably, there are AI technologies being developed to detect early signs of dementia through speech and language patterns analyzing short snippets of speech to predict and monitor cognitive decline (Kwak et al., 2021). AI-powered brain-computer interfaces such as "Neuralink" are also being worked on that can augment human cognition (Musk and Neuralink, 2020). Virtual reality (VR) environments powered by AI, such as those offered by "OxfordVR" provide

immersive experiences that can improve cognitive responses to real-life scenarios (Freeman et al., 2018).

Over-reliance on ChatGPT or similar AI platforms for answers and academic work and information can reduce an individual's ability to think critically and develop independent thought. These AI tools enable one to obtain quick answers and solutions to a wide range of questions and requests which can be tempting for individuals to rely on exclusively. However, this can limit an individual's ability to evaluate and analyze information critically and develop their own ideas and opinions.

8 Age groups

Digital use has differential influences across different age groups, with varying effects on children, young adults, and older adults. Understanding the specific effects and developmental factors that moderate these effects is crucial for promoting healthy and beneficial digital engagement across the lifespan.

8.1 Children

The effect of digital use on children is of great importance. On one hand interactive applications and digital media can not only enhance cognitive skills, creativity, digital literacy and an avenue to educate themselves. On the other hand, excessive and unmoderated digital use during childhood has been associated with adverse outcomes such as reduced attention spans, lower academic performances, and socio-emotional challenges due to limited social interactions. Mobile device use in toddlers was associated with lower expressive language skills (Radesky et al., 2014) and excessive screen time has been linked to deficits in cognitive development in children (Nikken and Schols, 2015).

8.2 Young adults

Young adults are the most engaged age groups when it comes to digital technology, with widespread use of social networking and social media platforms as well as entertainment and online communication channels. The impact of digital use on young adults can affect and influence various aspects of their lives such as their mental health, academic performance and socio-emotional status. The excessive use of social media platforms has been associated with negative psychological effects amongst young adults (Lin et al., 2016). The societal pressures relating to fashion, body weight, body image, self-esteem, facial features and socio-economic comparisons on social media platforms can have negative effects on wellbeing (Perloff, 2014). In addition, excessive engagements with digital technology, such as excessive use of Facebook, has been linked to lower academic performance among college students (Junco, 2012). Developmental factors such as time management skills and the ability to balance online and offline activities can moderate the impact of digital use on young adults (Kirschner and Karpinski, 2010). Additionally, digital use can also affect socio-emotional development. For example, excessive social media use has been linked to higher levels of loneliness and depressive symptoms in adolescents (Primack et al., 2017). Developmental factors such as

limited self-regulation skills and vulnerability to peer influence may amplify these effects (Odgers et al., 2019).

8.3 Older adults

While older adults may have lower rates of digital technology adoption, their engagement is increasing. Digital use among older adults can have potential benefits, including enhanced cognitive functioning, social connectedness, and access to health information. Cognitive training through digital platforms such as through computer programs, smartphone apps, wearables or web-based platforms offer exercises designed to target specific cognitive domains, such as memory, attention, and executive function, with the goal of improving overall cognitive abilities and everyday functioning (Ziegler et al., 2022). Social media use has also been associated with reduced loneliness and improved social support among older adults (Cotten et al., 2014). Engaging with digital technology, particularly brain-training apps and interactive games, has been found to have positive effects on cognitive abilities in older adults as well (Anguera et al., 2013). These activities can contribute to improvements in memory, attention, and problem-solving skills. Factors such as digital literacy, previous experience with technology, and personal preferences may influence the extent to which digital technology positively impacts cognitive abilities in older adults (Charness and Boot, 2009). Older adults may face challenges such as usability barriers, cognitive decline, and social isolation in their engagement with digital technology (Van Deursen and Van Dijk, 2011).

It is, therefore, important to consider age-appropriate guidelines and interventions that address the potential risks and benefits of digital technology for each age group. Further research is needed to explore the longitudinal effects of digital use on different age groups and to develop age-specific strategies for optimizing the benefits while mitigating potential risks.

9 Strategies to maximize benefits

Digital technology has transformed the way we live, work, and communicate. While these tools have many benefits, such as increased productivity, enhanced learning opportunities, and improved social connections, they also have a negative impact on brain development and cognitive function. However, there are many ways that this can be mitigated to exploit the benefits of the digital world. Easy habits such as

- **Digital Detox:** periods of abstinence from digital devices can restore cognitive functions and reduce stress levels (Duke and Montag, 2017). A digital detox can be done by scheduling screen-free spaces (digital-free zones at home), technology-free time periods or using old-fashioned alternatives (like reading a paper book or newspaper), or by spending more time outdoors. Take planned and regular breaks when using digital tools.
- **Mindful Technology Use:** encouraging mindful engagement with digital tools and social media can limit overuse and

foster healthier habits. This involves conscious decision-making about when, where, and how to use digital tools (Rosen et al., 2013a).

- Exercise and Physical Activity: regular physical activity can help counterbalance some of the negative impacts of excessive screen time. Exercise improves cognitive function, reduces anxiety and depression, and improves sleep quality (Sibley and Etnier, 2003).
- Training in Media Literacy and Digital Skills: educational programs can equip individuals with the skills to critically evaluate digital content, use digital tools responsibly, and understand their own digital habits (Hobbs, 2010). Utilizing mobile applications that help to track and limit time on certain applications and devices can also be encouraged.
- Setting up timers to focus on focused tasks: these habits can help in reducing digital distractions and thereby reduce the demands on their attentional resources and focus more effectively on the task at hand. Focusing on a single task at a time can improve performance and reduce feelings of stress (Ophir et al., 2009).

Further research is needed to better understand the complex relationship between technology and the brain, and to determine optimal ways to use digital tools for optimal cognitive health.

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