Understanding Today’s Learners: Cognitive Impacts of Technology Use on Adolescent Learning

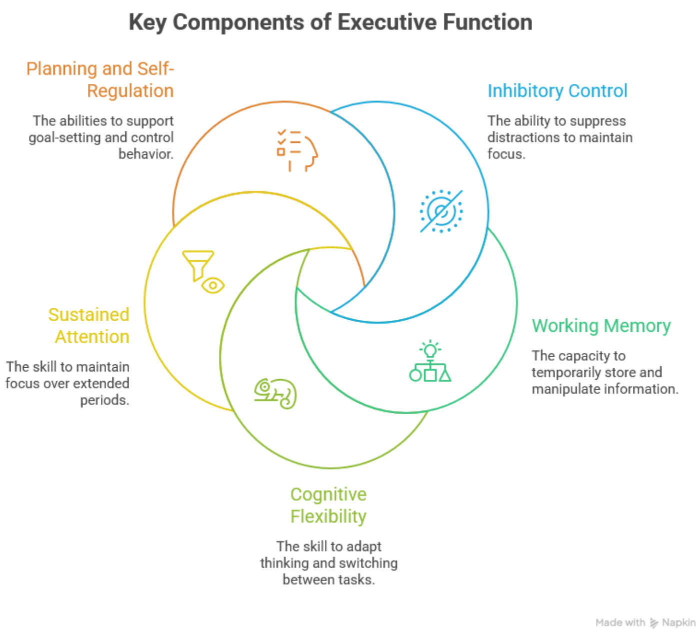
Michaela Arztmann & Tim Gallagher

Executive Summary

About this study

This study synthesizes evidence from systematic reviews, meta-analyses, and recent longitudinal and experimental research to examine how adolescents' technology use influences cognitive processes and learning outcomes. Given that adolescence is a period of rapid changes in brain structure and heightened sensitivity to environmental influences (Blakemore & Choudhury, 2006; Paulus et al., 2019), understanding how digital engagement interacts with developing cognitive systems is essential for designing effective educational strategies and promoting healthy learning habits.

Adolescents are increasingly engaging with multiple media sources at the same time. For example, they might browse an app while responding to messages and listening to music. This behaviour, known as media multitasking, has become a common feature of their daily routines and an important context in which cognitive processes are challenged and shaped (Carrier et al., 2009; van der Schuur et al., 2015). Cognitive processes play a central role in how students learn, remember, and apply knowledge. Key processes include inhibitory control, working memory, cognitive flexibility, sustained attention, and self-regulation (Cristofori, Cohen-Zimmerman & Grafman, 2019; Kennedy et al., 2008; Kong et al., 2023). These processes -which are collectively called *executive functions*- work together to support goal-directed behaviour, problem-solving, and adaptive responses to new situations. (Cristofori et al., 2019; Kennedy et al., 2008).



This review includes 22 systematic reviews and meta-analyses and 14 high quality- empirical studies published since 2023, focusing on cognitive control, academic achievement, and behavioural outcomes relevant to adolescent learners.

What did we find?

Problematic engagement with technology and not total time spent results in cognitive difficulties

Across multiple meta-analyses, simple screen time shows only weak associations with cognitive control (e.g., Howard et al., 2025; Kong et al., 2023). In contrast, problematic or compulsive patterns of use demonstrate substantially larger negative effects, particularly for self-regulation and inhibitory control (Howard et al., 2025). Heavy media multitaskers also show moderate deficits in executive functioning (Kong et al., 2023), with inhibitory control and working memory especially affected. Longitudinal evidence indicates that earlier problematic or multitasking behaviours predict later inattention, impulsivity, and reduced executive functioning (Thorell et al., 2024; Shan et al., 2025). These findings highlight that *how* adolescents use technology is more consequential than *how much* they use it.

Media multitasking negatively influences comprehension

Media multitasking is consistently linked to fragmented attention and reduced cognitive control (Kong et al., 2023). While some studies find minimal effects on sustained attention itself, multitasking during reading reliably predicts poorer text comprehension, even when attentional capacity is controlled for (Romero et al., 2025). Frequent task-switching increases cognitive load and disrupts the capacity to understand new information, contributing to lower academic performance (Leonhardt, Danielsen, & Andersen, 2025; Pyhältö et al., 2025). This aligns with the "scattered attention hypothesis," which proposes that rapid shifts between digital stimuli make sustained focus more difficult over time (Ophir et al., 2009; van der Schuur et al., 2015).

Not all technology use is equal: context and content matter

The cognitive and academic effects of technology use vary substantially depending on purpose and engagement type. Educational or goal -directed use can be beneficial (Marker et al., 2018), whereas task unrelated or emotionally intense use is consistently associated with poorer outcomes (Pyhältö et al., 2025). Content type also plays a role: educational content may have protective effects, while entertainment-oriented or problematic use is more strongly linked to deficits in executive functioning (Maeneja- et al., 2025; Marker er al. 2018). Longitudinal studies further show that certain activities - such as searching for educational information or listening to music- are associated with lower attention problems, whereas online gaming or adult content consumption predict higher initial deficits (Choe & Yu, 2024).

Sleep is important - late night use negatively affects sleep and consequently attention, learning outcomes and student well-being

Across multiple reviews, technology use (especially at night) is consistently associated with reduced sleep duration, poorer sleep quality, longer sleep onset latency, and increased daytime sleepiness (Lund et al., 2021; Silva et al., 2022; Dibben et al., 2023). Nighttime smartphone use predicts later attentional problems and lower school performance (Stevic et al., 2024), indicating- that sleep disruption has direct consequences for learning. Sleep also partially mediates the relationship between social media use and poorer well-being (Dibben et al., 2023). These findings highlight that late night- technology use not only undermines sleep but also affects attention, executive functioning, academic outcomes, and overall well-being.

Implications for educational practice

The findings of this review point to several actionable steps educators and schools can take to support today's students:

- **Cultivate deliberate attention (promote "single-tasking").** Because media multitasking and problematic smartphone use undermine inhibitory control, sustained attention, and self-regulation (Kong et al., 2023; Howard et al., 2025; Thorell et al., 2024), classrooms can incorporate short device- free focus intervals, structured reading blocks, and brief attention- training practices to help students strengthen single- tasking skills (Pyhältö et al., 2025).
- **Create predictable, structured classroom technology routines.** Because task unrelated and problematic use during academic activities is more harmful than overall use intensity (Marker et al., 2018; Paterna et al., 2024; Pyhältö et al., 2025), schools can adopt consistent "-device on/-device off-" routines. Clearly defined offline and online segments reduce distraction and help students internalize norms for focused technology use (Howard et al., 2025; Thorell et al., 2024).
- **Structure digital learning tasks to reduce cognitive load.** The reviewed work suggests that multitasking and frequent task switching increase cognitive load and fragment concentration during learning (Marker et al., 2018; Pyhältö et al., 2025). When digital tools are used in class, educators can reduce these costs by specifying clear task goals (e.g., a single platform or resource at a time), signalling when it is appropriate to switch between applications, and building in brief check ins for students to monitor their focus.

- **Strengthen digital literacy and self-regulation- curricula.** Digital stress, problematic use, and emotionally intense engagement show stronger links to academic achievement, well-being, and sleep difficulties than total time online (Keles et al., 2020; Khetawat & Steele, 2023; Dibben et al., 2023). Digital literacy programmes can therefore address emotion regulation, social comparison, fear of missing out, and boundary setting to help students navigate online pressures (Liu et al., 2022; Kokka et al., 2021).
- **Promote healthy sleep routines and boundaries.** Nighttime device use is consistently linked to reduced sleep quality and poorer daytime functioning (Lund et al., 2021; Silva et al., 2022; Dibben et al., 2023; Kokka et al., 2021). Schools can work with families to encourage device- free bedrooms, digital curfews, and homework schedules that avoid late- night online activity, highlighting how improved sleep supports attention, mood, and learning (Dibben et al., 2023; Kokka et al., 2021).
- **Tailor support to vulnerable groups.** Younger adolescents in general are more vulnerable. Schools can prioritize early adolescence for preventive digital literacy work and provide targeted support for students with attentional, behavioral, or emotional vulnerabilities (Thorell et al., 2024; Wallace et al., 2023; Xu et al., 2025).

Understanding Today’s Learners: Cognitive Impacts of Technology Use on Adolescent Learning

Today’s learners are growing up in an environment shaped by constant digital connectivity, engaging with technology in every aspect of their lives. Adolescents often use multiple media sources simultaneously - for example, they might browse in an app, while responding to messages and listening to music. This behaviour, known as media multitasking (e.g., Carrier et al., 2009; van der Schuur et al., 2015), has become a common feature of their daily routines. While media multitasking may feel intuitive to them, research suggests it can affect several aspects of cognitive functions relevant for learning, such as sustained attention, executive functioning, working memory, and impulsivity (Kong et al., 2023; Rioja et al., 2023; van der Schuur et al., 2015).

Some researchers refer to this phenomenon as the scattered attention hypothesis (Ophir, Nass, & Wagner, 2009; van der Schuur et al., 2015), where learners struggle to sustain focus on a single task for extended periods. Digital distractions, such as constant notifications, make it harder for learners to concentrate, which has been linked to longer time spent on reading tasks and lower academic performance (Leonhardt, Danielsen, & Andersen, 2025). On the other hand, relying on digital tools for information could improve memory capacity by outsourcing tasks to the phone (e.g., setting reminders), known as cognitive off-loading (Risko & Gilbert, 2016).

Understanding how digital habits shape the cognitive profile of today’s learners is essential for the IB and its educators, researchers, and policymakers. To design effective learning environments, we must first recognize how these technologies influence attention, memory, and learning itself.

1 Project goals

This research project aims to gain insight into how technology influences cognitive processes relevant to learning in adolescents. Given that this age group is still undergoing critical changes in brain structure (Paulus et al., 2019), it is important to understand how these technological influences interact with cognitive development to inform effective educational strategies and promote healthy learning habits.

Through this review, we aim to gain deeper insight into the types of cognitive processes involved, the advantages and challenges posed by technology use, and provide first indications on effective interventions and on how learning content should be designed for today’s learners.

2 What are cognitive processes relevant for learning?

Cognitive processes are central to how students learn, remember, and apply knowledge. Among the most important of these processes are inhibitory control, working memory, cognitive flexibility, sustained attention, and self-regulation (see e.g., Cristofori, Cohen-Zimmerman & Grafman, 2019; Kennedy et al., 2008, Kong et al., 2023). Together, these processes are known as executive functions - a broad term describing the cognitive control mechanisms that support goal directed behavior, problem solving, and adaptive responses to new situations (Cristofori et al., 2019; Kennedy et al., 2008). Executive functions manage and coordinate other cognitive systems, such as attention and memory, allowing individuals to inhibit automatic responses, handle competing information, and adapt behavior when circumstances change (Collette et al., 2006; Van der Linden et al., 2000).

The foundational components of executive function most relevant to learning include:

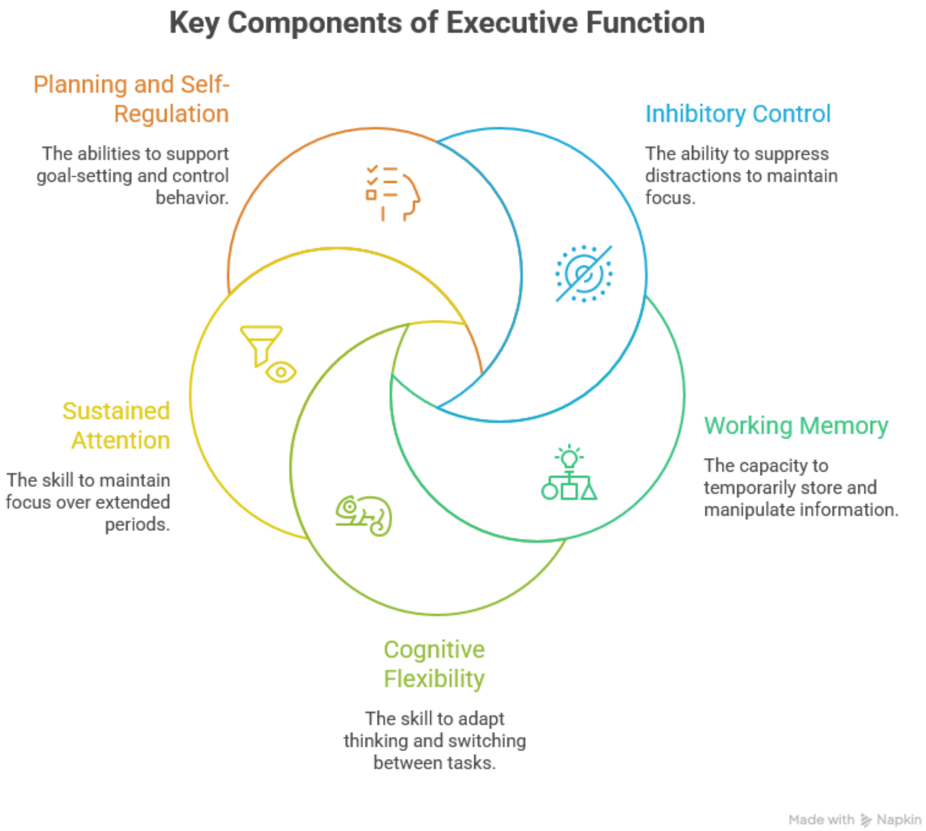
- **Inhibitory control**, which enables learners to suppress automatic responses, resist distractions, and maintain focus on relevant information while filtering out irrelevant stimuli. This skill is particularly important in technology rich environments where constant notifications and competing demands compete for attention.

- **Working memory**, which supports the temporary storage and manipulation of information needed for complex cognitive tasks. It allows learners to hold multiple pieces of information in mind, integrate new material with prior knowledge, and apply learned concepts to novel situations.

- **Cognitive flexibility (or shifting)**, which permits learners to adapt their thinking when rules or circumstances change, switch between different tasks or mental sets, and consider alternative perspectives, an essential capacity for navigating the multifaceted demands of modern learning environments.

- **Sustained attention**, which enables prolonged engagement with complex tasks and helps students maintain focus over extended periods despite distractions or competing demands.

- **Planning and self-regulation**, which integrate these capacities to support goalsetting, strategic thinking, emotional control, and behavioral monitoring. These higher order abilities allow learners to organize work, regulate their responses, and pursue long term objectives effectively.



These abilities are primarily governed by the prefrontal cortex and involve several core components (including selective attention, response inhibition, decision making, and working memory) that work together to enable cognitive control. In learning contexts, these functions help students focus on relevant information, filter out distractions, and plan actions toward long term goals (Blakemore & Choudhury, 2006). Adolescence represents a particularly important period for the development and refinement of these higher order abilities, marked by rapid neural reorganization and the maturation of prefrontal networks that underpin learning, self-regulation, and decision making (Cristofori, Cohen Zimerman, & Grafman, 2019; Paulus et al., 2019; Superbia-Guimarães & Cowan, 2023; Tervo-Clemmens et al., 2023). From late childhood through mid-adolescence (approximately ages 10-15), executive functions strengthen considerably and typically stabilize at adultlike levels by late adolescence (ages 18–20; Tervo-Clemmens et al., 2023).

This developmental window constitutes both a period of opportunity and vulnerability. While the strengthening of executive control enhances learning and self-regulation, these systems are also sensitive to environmental factors, such as technology use, stress, and social context, that can support or hinder their growth (Blakemore & Choudhury, 2006; Superbia Guimarães & Cowan, 2023). Deficits in executive functioning, whether arising from neurological factors, environmental influences, or behavioural patterns like excessive digital engagement, can negatively affect academic performance, decision making, and adaptive functioning (Cristofori et al., 2019; Kennedy et al., 2008; Paulus et al., 2019). When executive control systems are compromised, learners may struggle with planning, impulse regulation, and the flexible application of knowledge across contexts (Baddeley, 1996; Collette et al., 2006; Cristofori et al., 2019), these systems are also sensitive to environmental factors (Superbia Guimarães & Cowan, 2023).

Understanding how digital habits interact with these developing cognitive systems is essential for designing educational approaches that support, rather than undermine, adolescent learning and development.

3 Method

Published research on the effects of adolescents' media use on cognitive functions were searched in the database EBSCO. The aim was to discover all relevant studies; therefore, the search terms included a variation of synonyms of the media type and relevant outcome variable and were used in both subject headings and free text search. The search string can be found in the Appendix.

Additionally, the search was restricted to records published after 2015, with English as a publication language.

3.1 Inclusion of studies

The first database search resulted in 5151 papers. After deduplication, a total of 4921 papers were left for initial screening for which ASReview was used. ASReview is an open-source software tool, that combines human screening with machine learning, presenting the most relevant papers first based on previous screening decisions. 819 papers were identified for the full-text screening, of which 498 papers could be retrieved with existing licences. Given the number of papers and due to time constraints, it was decided to first start screening review articles before looking into other research articles. At each screening stage, 10% of records were independently screened by a second reviewer to establish inter-rater reliability of the screening criteria.

3.2 Inclusion of reviews and meta-analyses

Reviews were eligible for inclusion if they met the following criteria. Regarding population, reviews were required to focus on adolescents, defined variably across reviews but generally encompassing individuals aged approximately 11–19 years. Although adolescence is often defined as the developmental period between 10-19 years (World Health Organization, 2026), we limited this review to 11–19 years to align with secondary-school contexts and to reduce sample heterogeneity by excluding the late-primary transition year, which is educationally and developmentally distinct (Evans, Borriello & Field, 2018). Moreover, reviews including children or young adults were eligible if adolescents comprised the primary focus or if adolescent-specific findings were reported separately. Regarding exposure, reviews were required to examine technology use, including but not limited to smartphones, mobile phones, social media, internet use, screen time, electronic devices, and problematic or addictive patterns of technology engagement. Only systematic reviews with or without meta-analysis were eligible; narrative reviews without systematic search strategies were excluded. A detailed overview of the inclusion criteria can be found in Table 1.

Table 1: Inclusion and Exclusion criteria

Criteria	Inclusion	Exclusion
1 Language	English	Non-English
2 Availability	Full text is available	Full text is not available
3 Participants	aged 11-18, adolescents, secondary school students	non-adolescents
4 Outcome	**Cognition** (cognitive load, cognitive off-loading, cognitive control) **Brain development**, neural networks **Meta-Cognition** (self-regulated learning, problem solving, study strategies) **Executive functions** (attention, task switching, inhibition, working memory, flexibility) **Learning Outcomes** (retention, information retrieval) **Behavioural** (emotion, reward processing, impulsivity, sleep quality, depression, well-being)	Studies not focusing on any of those variables
5 Intervention/Exposure	**Digital devices:** smartphones, tablets, computers, laptops, screens, gaming consoles **Digital activities:** social media use, gaming, video streaming, messaging, web browsing, AI tool use (e.g., ChatGPT, Google search)	Studies that are not referencing digital technology in any way

	Behavioural patterns: media multitasking, digital distraction, task-switching, removal of access	
6 Study design *Quality criteria*	Meta-analyses Systematic reviews ESM/ EMA Longitudinal RCTs & quasi-experimental	Qualitative, non-systematic reviews. Intervention studies that have insufficient statistical information available to calculate effect size OR Method is not clearly described and cannot be reproduced based on the information available. OR Use of non-validated instruments. Correlational studies
7 Timeframe	Starting from 2015	Publication prior 2015

Of the 50 extracted review articles, 22 were included. Six focused on cognition, three on learning, and thirteen on behavioural outcomes such as well-being, sleep, and mental health. Given that the scope of this review is to understand the effect of media use on cognitive processes relevant for learning, and the relatively small amount of included reviews and meta-analyses compared to behavior, we decided to additionally screen relevant research articles. Since the most recent meta-analysis examining multiple variables of cognitive control was published in 2023 (Kong et al., 2023), we limited our full-text screening to studies published from 2023 onward to capture studies beyond its scope. Out of 163 identified studies, 14 met the quality criteria by demonstrating causal effects through quasi-experimental or randomized controlled designs, or by examining effects longitudinally. To support the synthesis of the included literature, Gemini Literature Review pipeline (Gallagher, 2025) was used to extract evidence, which was then cross-checked by the author.

4 - How does technology influence cognitive processes relevant for learning?

Key points

1) Problematic engagement -**not** total screen time- is the strongest predictor of cognitive difficulties
2) Problematic media use affects brain networks relevant for attention and self-regulation
3) Earlier technology use patterns predict later attention problems
4) **But:** early smartphone acquisition is not universally harmful, it interacts with existing habits
5) Media multitasking affects comprehension even when attention appears intact
6) Not all technology use is equal: content and purpose matter

The relationship between technology use and cognitive functioning has attracted considerable research attention, particularly as digital devices have become universal in adolescents' daily lives. Synthesizing evidence from six meta-analyses and systematic reviews alongside fourteen longitudinal and experimental studies, a relatively consistent pattern emerges: frequent and problematic technology use is associated with reduced cognitive control, though the magnitude and nature of these effects vary by technology type, usage pattern, and the specific cognitive domain assessed.

Meta-analytic evidence provides the most robust estimates of these associations. Howard et al. (2025), in a comprehensive synthesis of 183 studies encompassing over 234,000 participants from birth to adolescence, found a consistent pattern of negative associations between self-regulation (including attentional and cognitive control mechanisms) and digital engagement. Notably, these associations varied substantially by engagement type: while simple screen time showed only weak associations with self-regulation (r = -.04), problematic engagement with mobile phones demonstrated much larger effects (r = -.41), suggesting that how adolescents engage with technology matters more than time spent alone.

Kong et al. (2023) conducted a three-level meta-analysis specifically examining cognitive control in adolescents and young adults with varying media multitasking experience. Across 5194 participants, heavy media multitaskers demonstrated moderate deficits in overall cognitive control (d = -0.229) compared to light multitaskers. Importantly, moderator analyses revealed no significant difference between adolescents and young adults, indicating that the cognitive costs of media multitasking are not restricted to any specific developmental stage within this age range.

Systematic reviews of neuroimaging studies provide additional evidence at the neural level. León Méndez et al. (2024), reviewing 21 fMRI studies of adolescents and young adults with internet or smartphone addiction, documented functional abnormalities in brain regions critical for cognitive control, including the dorsolateral prefrontal cortex, anterior cingulate cortex, and parietal lobes. In adolescents specifically, internet addiction was linked to reduced functional connectivity in fronto-parietal circuits and ineffective connectivity in pathways supporting response inhibition. Schettler et al. (2022) reported similar findings in their systematic review of problematic gaming, noting reduced grey matter volume and altered activity in prefrontal regions associated with impulse control and decision-making among adolescent gamers.

The rapid systematic review by Maeneja et al. (2025), combining data from over 231,000 children and adolescents across nine countries, further confirmed that excessive exposure to information and communication technologies negatively affects multiple executive functions including working memory, inhibitory control, cognitive flexibility, and attention. However, the review also highlighted important nuance: educational content appeared to have protective or neutral effects compared to entertainment content, suggesting that content type modulates the cognitive impact of technology use. However, they only included one study that focused on educational content and as such this insight should be taken as an indication rather than a substantiated result.

4.1 Longitudinal evidence for directional effects

While cross-sectional and meta-analytic findings establish reliable associations, longitudinal studies provide critical evidence regarding the directionality of effects. Thorell et al. (2024), in their systematic review of longitudinal associations between digital media use and ADHD symptoms, found that 74% of studies reported significant associations between earlier technology use and later symptoms of inattention, hyperactivity, and impulsivity. The review articulated the “scan and shift hypothesis”, proposing that the rapid pace of digital media may gradually drain attentional resources, making sustained attention increasingly difficult over time. Effect sizes were generally small (correlation coefficients below .30), but the consistency of findings across diverse samples and methodologies lends confidence to causal interpretations.

Shan et al. (2025) tracked 609 Chinese adolescents over six months and found that media multitasking significantly predicted subsequent reductions in executive functioning (β = -0.38), with executive function in turn mediating effects on divergent thinking. This mediation pattern suggests that the cognitive costs of media multitasking may cascade to affect broader creative and academic capacities. Similarly, Stevic et al. (2024), following 384 German parent-child pairs, demonstrated that nighttime smartphone use predicted increased attentional problems over time (β = 0.11), which subsequently predicted lower school performance.

Wallace et al. (2023) employed sophisticated mediation modelling with 3,779 Canadian adolescents and found distinct pathways linking different technology types to cognitive outcomes. Social media use was longitudinally linked to ADHD symptoms through a pathway involving disrupted inhibitory control and impulsive temperament. Television viewing and video gaming showed associations with deficits in both response inhibition and working memory, though these appeared to reflect common vulnerability rather than within-person causal effects.

Other longitudinal work has revealed more nuanced patterns. Xu et al. (2025), analysing data from 3,954 adolescents in the ABCD study, found that the nature of engagement mattered substantially: while problematic social media use predicted increased attention problems in males (B = 0.139) and problematic mobile phone use predicted increased impulsivity in both sexes (B = 0.219 for females, B = 0.149 for males), problematic video game use was paradoxically associated with *fewer* attention problems and lower impulsivity. He et al. (2023), also drawing on the ABCD cohort, found that while increased social media use was associated with reduced volume in subcortical structures relevant to memory and cognitive control, screen media use was not significantly associated with behavioural measures of attention after correcting for multiple comparisons.

Choe and Yu (2024), tracking 2,092 Korean adolescents, demonstrated that not all technology use carries equivalent cognitive costs. While online gaming, watching videos, and accessing adult websites were associated with higher initial levels of attention deficit, searching for educational information and listening to music were associated with *lower* initial attention deficit. Gerosa and Gui (2023) found similarly conditional effects: early smartphone acquisition (ages 10-11 versus 12+) showed no overall effect on language proficiency, but for adolescents who were already heavy screen media users, early smartphone adoption significantly impaired language development (β = -0.222).

4.2 Media multitasking and smartphone use: Effects on attention and executive functions

Turning specifically to the question of how frequent media multitasking and smartphone use impact adolescents' attention spans and executive functions, the evidence base points toward consistent negative associations with small-to-moderate effect sizes.

The most direct evidence comes from Kong et al.'s (2023) meta-analysis, which examined specific executive function components. Heavy media multitaskers showed significantly poorer performance on inhibitory control tasks (d = -0.307) and working memory tasks (d = -0.243) compared to light multitaskers. Interestingly, no significant difference emerged for cognitive flexibility, suggesting that media multitasking may selectively impair certain executive capacities while leaving others intact. This pattern aligns with theoretical accounts proposing that the scattered attention characteristic of multitasking behaviour specifically taxes inhibitory and working memory systems while potentially preserving or even exercising task-switching abilities.

Howard et al.'s (2025) meta-analysis distinguished between media multitasking and smartphone use specifically. While media multitasking showed a small negative association with self-regulation (r = -.17), problematic mobile phone use demonstrated a substantially larger effect (r = -.41). Importantly, when adjusted for confounds, the association with amount of mobile phone use (as opposed to problematic use) became small and non-significant, underscoring that behavioural patterns and psychological dependency may be more consequential than exposure duration alone.

Thorell et al. (2024) found longitudinal evidence that media multitasking specifically predicts later inattention, with these effects particularly pronounced in younger adolescents and girls. High mobile phone use was independently linked to increased risk of ADHD symptoms. However, the review noted a significant gap in the literature; while associations with attention are well-documented, longitudinal studies investigating specific executive functions such as working memory or inhibitory control as mediating mechanisms remain scarce.

Individual studies provide additional texture to these findings. Shan et al. (2025) found that frequent media multitasking strongly predicted subsequent decrease in a composite measure of executive functioning encompassing inhibitory control, cognitive flexibility, and working memory (β = -0.38). Romero et al. (2025) examined adolescent secondary school students and found that, while media multitasking reading habits were not significantly correlated with sustained attention (r = -0.02), they were associated with poorer text comprehension, even when controlling for attention. This suggests that multitasking may affect cognitive performance through pathways beyond simple attentional capacity.

Neuroimaging evidence from León Méndez et al.'s (2024) systematic review identified specific neural signatures of these behavioural patterns in adolescents. Internet addiction was associated with reduced functional connectivity in fronto-parietal circuits essential for attentional control and ineffective connectivity in pathways supporting response inhibition. These neural-level findings complement the behavioural evidence, suggesting that habitual patterns of divided attention and problematic technology engagement may shape the developing brain's capacity for sustained focus and cognitive control.

In summary, the evidence consistently indicates that frequent media multitasking and problematic smartphone use are associated with diminished attention and executive functioning in adolescents, with meta-analytic effect sizes in the small-to-moderate range. Inhibitory control and working memory appear particularly vulnerable, while cognitive flexibility may be relatively preserved. The pattern of findings suggests that intervention efforts should focus not only on reducing screen time, but on addressing the qualitative nature of technology engagement, particularly patterns of divided attention and psychological dependency that characterise problematic use.

5 What is the effect of media multitasking and technology use on different types of learning outcomes?

Key points

1. Problematic and task-unrelated technology use consistently predicts lower academic achievement
2. Younger students are more vulnerable
3. Multitasking during academic work is especially harmful
4. Problematic use patterns -**not** total screen time- drive negative outcomes
5. Context matters: educational use of technology can support learning

Beyond effects on underlying cognitive processes, a separate body of research has examined the direct relationship between technology use and academic achievement. Two recent meta-analyses and a systematic review, which collectively combined data from over 120,000 students, provided consistent evidence that the use of technology in a problematic or task-unrelated manner is negatively associated with academic outcomes. However, the effect sizes were all small.

Paterna et al. (2024), in a meta-analysis of 48,490 students ranging from elementary school through tertiary education, found a small but reliable negative relationship between problematic smartphone use and academic achievement (r = -0.110). Notably, moderator analyses revealed that this association was significantly stronger, reaching a medium effect size, in samples of elementary and middle school students compared to older students. This developmental pattern suggests that younger adolescents may be particularly vulnerable to the academic costs of problematic smartphone engagement, perhaps because their self-regulatory capacities and study habits are still consolidating.

Marker et al. (2018) examined the relationship between social networking site (SNS) use and academic achievement across 29,337 adolescents and young adults. General SNS use showed a small negative association with grades and GPA (ρ = -0.07), while SNS use specifically during academic tasks (i.e., media multitasking) demonstrated a somewhat larger negative effect (ρ = -0.10). However, the meta-analysis also revealed an important exception: SNS use for explicitly academic purposes (such as collaborative learning or accessing educational content) showed a small *positive* association with academic achievement ($\rho = 0.08$). This pattern reinforces the recurring finding that the purpose and context of technology use matter substantially; social media is not generally harmful to learning when deployed in educationally purposeful ways.

Pyhältö et al. (2025), in a systematic review of 46,093 children and adolescents aged 7-18 attending primary and secondary school, found that task-unrelated social media and smartphone usage was generally negatively associated with academic achievement. While studies examining simple use intensity showed mixed results, problematic use patterns and multitasking during academic work were consistently linked to poorer outcomes. The review highlighted a plausible mechanism: multitasking and frequent task-switching driven by task-unrelated smartphone notifications increase cognitive load and fragment concentration. This leaves fewer cognitive resources available for encoding and understanding learning materials.

Importantly, the current evidence base reveals notable gaps regarding specific mechanisms linking technology use to learning outcomes. None of the included reviews provided evidence addressing cognitive off-loading (the phenomenon whereby learners rely on digital devices for information storage and retrieval), potentially affecting memory retention and metacognitive skill development (Risko & Gilbert, 2016). While theoretical accounts suggest that outsourcing memory tasks to smartphones may alter how learners encode and retrieve information, empirical investigation of these effects in adolescent populations remains limited. Similarly, while Pyhältö et al. (2025) identified cognitive load and attentional fragmentation as likely mediating mechanisms, direct experimental investigation of how digital distractions affect cognitive load during learning tasks in adolescents is sparse.

In sum, the relationship between technology use and academic achievement mirrors the pattern observed for cognitive processes: small but consistent negative associations, with effect sizes indicating that technology use accounts for only a small amount of the variance in academic outcomes. The evidence indicates that problematic engagement patterns and multitasking behaviour have significant negative consequences. On the other hand, purposeful academic use of technology may support learning rather than undermine it. Younger adolescents appear more vulnerable to these effects than older students, highlighting the importance of developing age-appropriate approaches to improving digital literacy education, for example. Future research should directly examine the mechanisms through which technology use affects learning, particularly the roles of cognitive off-loading and attentional disruption during study.

6 What is the influence of technology use on adolescents' behavior (i.e., well-being and sleep quality)?

Key points

1. Technology use is linked to small but reliable decreases in adolescent well-being.
2. Digital stress factors (e.g., fear of missing out, connection overload, approval anxiety), not time spent, are the strongest predictor of poor well-being.
3. Sleep outcomes show the strongest and most consistent negative associations with technology use.
4. Night-time and bedtime use show much stronger associations with poor sleep than daytime use.
5. Sleep disruption is a key mechanism linking technology use to poorer mental health.
6. Girls show stronger associations between technology use, depressive symptoms, and sleep disruption.
7. Age effects vary, but some evidence suggests younger adolescents may be more vulnerable.

While studies explicitly examining the cognitive effects of technology use have seemingly grown only in recent years, a much broader collection of research has explored its associations with behaviour and well-being, particularly around the time of the pandemic when digital media became an even more central part of adolescents' lives (Ivie et al., 2020; Keles et al., 2020; Liu et al., 2022; Dibben et al., 2023). Across these studies, a consistent pattern emerges. Technology use during adolescence tends to be associated with poorer psychosocial adjustment and lower sleep quality (Fischer-Grote et al., 2021; Lund et al., 2021; Kokka et al., 2021). Yet, these effects are typically small, and the evidence remains highly heterogeneous. The strength and direction of associations vary depending on the type of technology engagement, the outcomes assessed, and contextual factors such as timing of use and individual user characteristics (Khetawat & Steele, 2023; Dibben et al., 2023).

6.1 Well-being outcomes

Across six reviews, evidence suggests small but reliable associations between technology use, especially social media engagement, and poorer well-being in adolescents (Ivie et al., 2020; Keles et al., 2020; Liu et al., 2022; Fischer-Grote et al., 2021; Khetawat & Steele, 2023; Dibben et al., 2023). Ivie et al. (2020), in a meta-analysis, suggest a positive association between increased social media use and elevated depressive symptoms, with effect sizes in the small range ($r = -0.12$). Moreover, dose-response evidence suggests a linear relationship: increased daily time on social media corresponds to higher depression risk. Each additional hour is associated with approximately a re (Liu et al., 2022). However, heterogeneity across studies is consistently very high, indicating substantial variability that is not fully accounted for by commonly tested moderators such as age or sample size (Ivie et al., 2020; Liu et al., 2022).

Stronger associations emerge when technological use is conceptualized not in terms of duration, but in terms of psychological strain and problematic engagement. Khetawat and Steele (2023) conducted a meta-analysis of digital stress components, including fear of missing out, approval anxiety, availability stress, connection overload, and online vigilance. Their findings demonstrate medium-sized associations with psychosocial distress ($r \approx .26$-$.34$). These effects are notably larger than those observed for general social media use, suggesting that subjective experiences of pressure, obligation, and constant connectivity may be more harmful to adolescent well-being than exposure time alone. The systematic review of Keles et al. (2020) further supports this distinction, consistently finding that investment, emotional engagement, and addictive or problematic patterns of use show more robust associations with depressive symptoms, anxiety, and psychological distress than simple measures of time spent online.

Evidence regarding broader quality-of-life indicators is more limited and mixed. Reviews focusing on problematic smartphone use generally report negative associations with quality of life and subjective well-being, though findings for life satisfaction are inconsistent and based on a small number of studies (Fischer-Grote et al., 2021). Collectively, the well-being literature points toward modest average effects that may nonetheless be meaningful at the population level, particularly given the ubiquity of digital technology use during adolescence.

Several reviews highlight sleep as a potential explanatory mechanism linking technology use to poorer mental health. Mediation analyses consistently indicate that sleep disruption partially accounts for associations between social media use, nighttime phone use, and adverse well-being outcomes, with mediation effects ranging from approximately 5% to over 30% and generally stronger for girls than boys (Dibben et al., 2023). These findings suggest that technology-related impacts on well-being may operate indirectly through interference with sleep processes.

6.2 Sleep quality outcomes

Evidence regarding sleep outcomes is notably more consistent than that for well-being. Across five narrative reviews, technology use is reliably associated with poorer sleep across multiple parameters, including reduced sleep duration, poorer subjective sleep quality, longer sleep onset latency, later bedtimes, and increased daytime sleepiness (Lund et al., 2021; Silva et al., 2022; de Sá et al., 2023; Dibben et al., 2023; Kokka et al., 2021). These associations are observed across childhood and adolescence but appear particularly pronounced in adolescents, for whom mobile phones, computers, video games, and social media use are most relevant (Lund et al., 2021).

A recurring theme across reviews is that nature, timing, and context of technology use are critical. Night-time and bedtime use consistently show stronger associations with adverse sleep outcomes than general daytime use, and the presence of devices in the bedroom emerges as a potential independent risk factor (Lund et al., 2021; Silva et al., 2022; de Sá et al., 2023). Reviews examining interactive electronic device use further underscore that general use often shows weak or null associations with sleep, whereas adverse use patterns (e.g., overuse, problematic use, cyber-victimization) are much more consistently linked to sleep disruption (Dibben et al., 2023).

Problematic internet use demonstrates robust negative associations with sleep quality, duration, and insomnia symptoms, often in a dose-response pattern (Kokka et al., 2021). Even moderate levels of problematic use are associated with poorer sleep quality, and adolescents with problematic use patterns report substantially shorter sleep duration compared to regular users (Kokka et al., 2021). These findings reinforce the broader conclusion that the qualitative aspects of engagement, rather than the use of technology itself, are central to understanding sleep-related risks.

Despite the consistency of findings, the predominance of cross-sectional designs limits causal inference. It remains unclear whether technology use leads to sleep problems, whether sleep difficulties increase technology use, or whether both are driven by shared underlying factors (Lund et al., 2021; Dibben et al., 2023).

6.3 Moderators and differential effects

Moderator analyses across reviews suggest that associations between technology use and adverse outcomes are not uniform. Gender emerges as the most consistent moderator, with several reviews reporting stronger associations for girls than boys, particularly for depressive symptoms and sleep-related outcomes (Liu et al., 2022; Dibben et al., 2023; Keles et al., 2020). These differences may reflect gendered patterns of technology use, such as greater social media engagement among girls. Age effects are less consistent, with some evidence suggesting stronger associations in younger adolescents, but findings vary across outcomes and reviews (Keles et al., 2020; Liu et al., 2022; Lund et al., 2021).

Across both well-being and sleep domains, technology type and usage context appear to be key sources of variability. General device use is often weakly associated with, or not associated at all with, adverse outcomes. However, problematic, excessive, or psychologically demanding forms of engagement show more robust and consistent links (Dibben et al., 2023; Kokka et al., 2021). Night-time use and leisure-oriented engagement appear particularly relevant risk factors (Lund et al., 2021; Kokka et al., 2021). Taken together, the evidence indicates that adolescent technology use is associated with small but reliable increases in depressive symptoms and consistent impairments in sleep quality, with stronger effects observed for problematic use patterns, digital stress, and night-time engagement (Ivie et al., 2020; Liu et al., 2022; Khetawat & Steele, 2023; Lund et al., 2021).

7 Discussion

In conclusion, the reviewed evidence reveals that adolescents' technology use is not necessarily harmful. However, the way technology is used and its purpose critically determines whether it supports or hinders cognitive and learning processes (e.g., Howard et al., 2025; Kong et al., 2023; Maeneja et al., 2025; Paterna et al., 2024). Frequent problematic or multitasking patterns of use are associated with small-to-moderate reductions in executive functioning and attention, while educational and goal-directed uses may have neutral or even positive effects on achievement (Marker et al., 2018; Pyhältö et al., 2025). These findings collectively emphasize that the quality of engagement, rather than the quantity of screen time alone, represents the key driver of cognitive and academic outcomes (Howard et al., 2025; Thorell et al., 2024).

From a developmental perspective, adolescence represents a sensitive period for shaping the neural systems that underlie attention, self-regulation, and learning (Blakemore & Choudhury, 2006; Paulus et al., 2019; Tervo-Clemmens et al., 2023). The frontal and fronto-parietal circuits supporting executive control are still maturing during these years, making them particularly responsive to environmental demands (Cristofori et al., 2019; Superbia-Guimarães & Cowan, 2023). Technology use that fragments attention or encourages habitual task switching may overstimulate these still-developing networks, reinforcing shallow processing and impulsive response styles (Ophir et al., 2009; Thorell et al., 2024). On the other hand, well-designed digital learning environments can provide opportunities for adolescents to practice self-regulation, goal-setting, and metacognitive strategies in ways that align with their heightened drive for exploration and novelty (Risko & Gilbert, 2016; Howard et al., 2025).

At the same time, the size of the reported effects underscores the need for measured interpretation. The pattern across domains is characterized by small average associations (e.g., around -0.07 to -0.17 for social media and academic outcomes, and around -0.10 to -0.30 for problematic use and cognitive or behavioral difficulties; Ivie et al., 2020; Marker et al., 2018; Paterna et al., 2024). These effect sizes indicate that while technology-related cognitive and academic costs are meaningful, they explain only a fraction of the variance in learning outcomes (Howard et al., 2025). Broader contextual factors (such as classroom climate, instructional quality, sleep, and psychosocial well-being) play equally, if not more, substantial roles (Lund et al., 2021; Dibben et al., 2023; Kokka et al., 2021). The evidence therefore supports a shift away from generic screen time discourses toward a focus on digital balance and intentionality: helping students understand *when* and *how* to use technology in ways that foster learning rather than disrupt it (Pyhältö et al., 2025; Maeneja et al., 2025).

7.1 Implications for Educational Practice

For educators, curriculum designers, and schools, several actionable implications follow from this review.

- **Teach deliberate attention.** Given that media multitasking and problematic smartphone use are consistently linked to diminished inhibitory control, sustained attention, and self-regulation (Kong et al., 2023; Howard et al., 2025; Thorell et al., 2024), classrooms can deliberately cultivate “single-tasking” as a skill. Brief practices such as focused reading blocks without devices, short mindfulness-style attention exercises, or structured “distraction-free” work intervals provide students with repeated opportunities to practice sustained attention in contrast to their typical multitasking habits (Pyhältö et al., 2025).

- **Design structured digital tasks.** The reviewed work suggests that multitasking and frequent task-switching increase cognitive load and fragment concentration during learning (Marker et al., 2018; Pyhältö et al., 2025). When digital tools are used in class, educators can reduce these costs by specifying clear task goals (e.g., a single platform or resource at a time), signaling when it is appropriate to switch between applications, and building in brief check-ins for students to monitor their focus. Simple design elements, such as stepwise task sequences, visible progress indicators, and prompts to summarize what has been learned before moving can help students sustain attention and integrate information more deeply (Cristofori et al., 2019; Kennedy et al., 2008).

- **Promote metacognitive awareness and healthy off-loading.** The literature on cognitive off-loading suggests that outsourcing memory tasks to devices can be adaptive but may also change how information is encoded and retrieved (Risko & Gilbert, 2016). Although empirical work with adolescents is still limited, teachers can already help students reflect on *what* they delegate to devices (e.g., deadlines, schedules) versus *what* they aim to remember themselves (e.g., core concepts, vocabulary). Classroom discussions and planning activities that make these choices explicit can foster metacognitive insight into their own digital habits and support the development of more intentional off-loading strategies (Maeneja et al., 2025).

- **Optimize the classroom technology environment.** Evidence that task-unrelated and problematic use during academic activities is more harmful than overall use intensity (Marker et al., 2018; Paterna et al., 2024; Pyhältö et al., 2025) supports structured approaches to classroom devices. Rather than banning smartphones or laptops outright, schools can implement predictable “device-on/device-off” routines: for example, designated “offline” segments for direct instruction and deep work, followed by clearly marked “online” segments for research, collaboration, or digital practice. Such routines reduce the need for constant self-control in the face of notifications and help adolescents internalize situational norms for focused technology use (Howard et al., 2025; Thorell et al., 2024).

- **Strengthen digital literacy and self-regulation curricula.** Across well-being and sleep outcomes, patterns of digital stress, problematic use, and emotionally intense engagement show stronger links to difficulties than simple time online (Keles et al., 2020; Khetawat & Steele, 2023; Dibben et al., 2023). Digital literacy programs can therefore move beyond technical competencies to explicitly address emotion regulation, social comparison, and the management of online pressures. Embedding discussions of fear of missing out, approval anxiety, and boundary-setting into social-emotional learning curricula can equip students with tools to navigate digital environments more safely (Liu et al., 2022; Kokka et al., 2021).

- **Support healthy sleep routines and boundaries.** The consistent association between night-time device use, reduced sleep quality, and poorer daytime functioning underscores sleep as a central pathway linking technology use to cognitive and emotional outcomes (Lund et al., 2021; Silva et al., 2022; Dibben et al., 2023; Kokka et al., 2021). Schools can collaborate with families to promote routines such as "bedroom-free" phones, digital curfews before bedtime, and homework schedules that minimize late-night online activity. Sleep-focused education for students, parents, and teachers can highlight how even small changes in night-time use can translate into gains in attention, mood, and learning the next day (Dibben et al., 2023; Kokka et al., 2021).

- **Tailor supports to vulnerable groups.** Several reviews indicate that younger adolescents and girls may show stronger associations between digital engagement and depressive symptoms or sleep difficulties (Keles et al., 2020; Liu et al., 2022; Dibben et al., 2023). In line with these patterns, schools can prioritize early adolescence as a key window for preventive work (e.g., targeted digital literacy modules, mentoring, or group interventions) while remaining attentive to students who already exhibit attentional, behavioral, or emotional vulnerabilities (Thorell et al., 2024; Wallace et al., 2023; Xu et al., 2025).

7.2 Limitations and Future Directions

One of the main limitations of the included literature is that the evidence base remains uneven, which complicates the interpretation of results and the development of effective solutions. Many studies rely on self-reported measures of technology use and multitasking, which are prone to recall bias and may not accurately capture the complexity of adolescents' digital contexts (Marker et al., 2018; Pyhältö et al., 2025; Lund et al., 2021). Longitudinal and experimental studies that directly target specific executive functions as mechanisms are still scarce (Kong et al., 2023; Thorell et al., 2024). Furthermore, the dominance of Western, high-income samples constrains the cross-cultural generalizability of findings, particularly given known differences in technology access, school systems, and family norms around device use (Maeneja et al., 2025; Kokka et al., 2021).

Important conceptual gaps also remain. None of the included reviews systematically examined cognitive off-loading in adolescents, leaving open questions about how smartphone-based outsourcing of memory affects long-term retention and metacognitive skill development (Risko & Gilbert, 2016). Similarly, impulsivity and related self-regulatory traits are rarely integrated across cognitive, academic, and well-being domains, despite being implicated in problematic technology use, ADHD symptoms, and sleep disturbance (Howard et al., 2025; Thorell et al., 2024; Khetawat & Steele, 2023).

What does this mean for educators?

Technology is not *good* or *bad* in itself; the main risks come from constant multitasking, late-night or problematic use, not from screen time alone (e.g., Kong et al., 2023; Paterna et al., 2024; Lund et al., 2021).

1. Emphasize purposeful use

- Make a clear distinction between *learning use* (research, writing, collaboration) and *leisure use* (social media, gaming).
- During lessons, keep devices tied to a specific task and platform, rather than open, multi-app use.

2. Protect attention in the classroom

- Build short, regular “single-task” periods (e.g., 10–15 minutes of focused reading or problem-solving with notifications off).
- Use simple classroom rules such as *devices down for explanation, devices up for task*, so students are not constantly monitoring their phones.

3. Talk about digital habits and off-loading

- Discuss with students when it is helpful to rely on devices (e.g., reminders) and when it is important to remember ideas themselves (e.g., key concepts, vocabulary).
- Integrate brief reflection activities on how often they switch tasks and how this affects their concentration and understanding.

4. Link technology to sleep and well-being

- Highlight that late-night phone and social media use can reduce sleep and next-day focus and mood.
- Encourage class and whole-school messages about keeping devices out of bedrooms and having a “digital curfew” on school nights.

5. Pay attention to students who struggle

- Be especially attentive to younger adolescents and those already showing signs of attention problems, sleep difficulties, or high distress related to online life.
- Coordinate with families and support staff when patterns of problematic use (e.g., constant checking, late-night use, strong distress when offline) start to affect learning or well-being.

8 Conclusion

In summary, the evidence suggests that technology is neither the root of all problems nor the key to solving them when it comes to adolescent learning and development. Its influence is complex, deserving neither uncritical enthusiasm nor excessive worry. Adolescents are not simply hindered by digital distractions, nor are they “digital natives” unaffected by them; they are developing minds learning to make sense of cognitive and social worlds that are more complex and fast-changing than those experienced by previous generations (Blakemore & Choudhury, 2006; Ivie et al., 2020; Howard et al., 2025).The challenge for educators and policymakers is therefore not to shield students from technology altogether, but to equip them with the cognitive and self-regulatory tools needed to engage with it productively (Kong et al., 2023; Pyhältö et al., 2025). Thoughtful integration of digital awareness, attentional training, and structured learning design offers a practical route toward learning environments that acknowledge the realities of adolescents’ digital lives while safeguarding their capacity for focus, deep learning, and well-being (Maeneja et al., 2025; Lund et al., 2021; Dibben et al., 2023).

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Appendix

Search string for EBSCO

(TI(adolescen* OR teen* OR youth OR "middle school*" OR "high school*" OR "secondary school*")

OR AB(adolescen* OR teen* OR youth OR "middle school*" OR "high school*" OR "secondary school*"))

AND

(TI("media multitask*" OR (media N3 multitask*) OR "digital multitask*" OR smartphone* OR "mobile phone*" OR "push notification*" OR notification* OR "cognitive offload*" OR "AI tutor*" OR ChatGPT OR "generative AI" OR "large language model*" OR "media multitasking index" OR MMI OR "heavy media multitask*" OR "internet use" OR "web browsing"

OR "social media" OR streaming OR "online video*"

OR gaming OR "video game*" OR "computer game*" OR "serious game*" OR "game-based learning" OR "educational technolog*")

OR

AB("media multitask*" OR (media N3 multitask*) OR "digital multitask*" OR smartphone* OR "mobile phone*" OR "push notification*" OR notification* OR "cognitive offload*" OR "AI tutor*" OR ChatGPT OR "generative AI" OR "large language model*" OR "media multitasking index" OR MMI OR "heavy media multitask*" OR "internet use" OR "web browsing"

OR "social media" OR streaming OR "online video*"

OR gaming OR "video game*" OR "computer game*" OR "serious game*" OR "game-based learning" OR "educational technolog*")

)

AND

(TI(attention OR "sustained attention" OR distract* OR "executive function*" OR "working memory" OR "inhibitory control" OR "cognitive control" OR "task switch*" OR "cognitive load" OR metacogn* OR "self-regulat*" OR "learning outcome*" OR "academic achievement" OR retention OR impuls* OR sleep OR wellbeing OR depression OR "brain development")

OR

AB(attention OR "sustained attention" OR distract* OR "executive function*" OR "working memory" OR "inhibitory control" OR "cognitive control" OR "task switch*" OR "cognitive load" OR metacogn* OR "self-regulat*" OR "learning outcome*" OR "academic achievement" OR retention OR impuls* OR sleep OR wellbeing OR depression OR "brain development"))

NOT (TI OR AB)(college OR universit* OR undergraduate* OR "higher education" OR preschool OR "elementary school*" OR "primary school*")