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Managing attention in the age of fragmentation: cognitive load and self-regulation in lower secondary school

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Abstract: The increasing fragmentation of digital experience exposes pupils to notifications, interruptions, frequent task-switching and media multitasking, which may interfere with attention, increase cognitive load and challenge self-regulation. This study examined the effects of a school-based programme on attention hygiene and digital wellbeing among lower secondary school pupils. A convergent mixed-methods design was adopted within a class-randomised controlled trial. The initial sample comprised 192 pupils aged 11–14, assigned to either the experimental group or an active control group. The ten-week programme included education on the economics of attention, monotasking activities, notification management, study planning, metacognitive practices and self-regulation strategies. Quantitative outcomes were assessed using the d2-R, the Child and Adolescent Mindfulness Measure,

the BRIEF-2, Paas's cognitive load scale, a comprehension test and a digital interruptions diary. Focus groups with students, teacher interviews and reflective diaries formed the qualitative component. Simulated results indicated improvements in selective attention, attentional awareness and self-regulation in the experimental group, together with reduced cognitive load and multitasking. The integration of quantitative and qualitative findings suggests that effectiveness depends not simply on reducing screen time, but on developing intentional strategies to organise the environment, recognise distractions and preserve continuity in the learning experience during everyday school learning activities.

Keywords: attention economy; cognitive load; self-regulation; media multitasking; digital wellbeing.

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1. Introduction

The growing integration of digital technologies into everyday life has profoundly changed the ways in which children and adolescents access information,

communicate, learn and organise their time. Smartphones, social media platforms, online learning environments, messaging systems, video games and audiovisual content are now commonplace features of the developmental experience. These tools offer significant opportunities in terms of accessibility, participation, personalisation and the expansion of educational resources, but they also introduce new forms of cognitive demand, characterised by the co-occurrence of stimuli, rapid switching between activities and the constant availability of information.

The educational issue, therefore, does not lie simply in the presence of these technologies, but concerns the conditions under which they interact with processes of attention, working memory, inhibitory control and self-regulation. Recent literature, in fact, calls for moving beyond linear interpretations suggesting that greater screen time automatically leads to a decline in cognitive abilities. The effects depend on the content, the purpose, the social context, the level of interactivity, the user's age and, above all, the degree of fragmentation of the digital experience (Vedechkina & Borgonovi, 2021; Santos et al., 2022; Thorell et al., 2024). The distinction between intentional use, passive use, multitasking, compulsive browsing and functional use for study purposes therefore appears essential for correctly interpreting the relationship between technology and attention.

The available interdisciplinary reviews show that the digital experience can involve different processes, including attention, memory and social cognition, but they also highlight the heterogeneity of the effects and the need to avoid causal inferences based solely on usage time, particularly during adolescence (Firth et al., 2019; Odgers & Jensen, 2020; Wilmer et al., 2017).

The concept of the 'economy of attention' allows us to situate these transformations within a broader perspective. Simon (1971) had already observed that an abundance of information leads to a corresponding scarcity of attention, since every increase in available content heightens the need to select what is worth processing. In today's digital ecosystem, attention is not merely an individual cognitive resource, but also a contested asset among platforms, services and devices, whose economic value is often linked to their ability to attract, retain and re-engage users (Davenport & Beck, 2001; Citton, 2017; Zuboff, 2019).

Notification systems, autoplay, continuous updates, algorithmic personalisation and intermittent rewards can encourage repeated, brief and largely unplanned interactions. These characteristics do not necessarily lead to addiction or attention deficits, but they contribute to the creation of environments in which students are subjected to numerous occasions requiring them to direct and redirect their attention. The central issue is not merely how much time is spent online, but how often the current activity is interrupted, how salient competing stimuli are, and how many resources

are required to resume the main task.

This distinction is confirmed by the most recent evidence. Telzer and Burnell (2026), using objective data on smartphone use during the school day, found that the frequency of checking the device was associated with less effective cognitive control, whilst the total time spent using it did not show the same relationship. Although these are cross-sectional data that do not allow a causal direction to be established, the result suggests that the temporal structure of use – and in particular the succession of brief, repeated checks – may be more significant than the duration of exposure alone. Attentional fragmentation can be defined as the continuous division of cognitive experience into short segments, interrupted by competing demands or by frequent switching between content, applications and activities. It can stem from external stimuli, such as a notification or a message, but also from internal impulses, such as the desire to check the device, the search for novelty or the anticipation of a possible social reward. This results in an experiential pattern in which attention is repeatedly diverted, reallocated and reconstructed.

Digital interruptions do not always coincide with lengthy or overtly intrusive events. Even brief stimuli can interfere with the maintenance of the active goal in working memory. Upshaw et al. (2022), using behavioural and electrophysiological measures, found that smartphone notifications can alter cognitive control processes, even when they do not require prolonged interaction. Similarly, experimental studies on distraction highlight that the cost stems not only from the time physically taken away from the task, but also from the resources expended in inhibiting the stimulus, shifting focus and subsequently reconstructing the sequence of the activity.

However, the hypothesis that the mere presence of a smartphone is always sufficient to reduce cognitive performance should be interpreted with caution. The meta-analysis by Hartanto et al. (2024), based on 166 effect sizes from 53 samples, did not find a statistically significant average effect of the mere presence of the device on cognitive outcomes. This finding puts some previous conclusions into perspective and shows that the physical presence of a smartphone cannot, in itself, be considered a universal cause of cognitive impairment. The effects appear to depend on the importance attributed to the device, expectations of receiving messages, the type of task and individual characteristics.

A substantial body of literature has focused on media multitasking, understood as the simultaneous or rapidly alternat l use of multiple media and information streams. Contrary to the subjective perception of simultaneity, in complex cognitive tasks, multitasking frequently consists of a succession of shifts in attentional focus. Each transition requires the suspension of the previous cognitive set, the activation of new operational rules and the retrieval of the information necessary for the subse-

quent task. This process can result in costs in terms of time, accuracy and depth of processing.

Pioneering studies by Ophir et al. (2009) linked high levels of media multitasking to greater susceptibility to irrelevant information. Subsequent research, however, has produced results that are not always consistent, highlighting the need to consider methodological and individual differences (Wiradhany & Nieuwenstein, 2017; Vedechkina & Borgonovi, 2021). The evidence is more consistent when multitasking is observed during learning activities: switching between studying and irrelevant communications can reduce comprehension, the quality of notes and information retention, especially when competing activities use the same sensory channels or require overlapping linguistic processing.

The systematic review by Martin et al. (2025) shows that digital distraction in educational contexts stems from the interaction between technological characteristics, personal needs and the configuration of the learning environment. The most frequently reported consequences include loss of focus, reduced performance, difficulties in following instructions and problematic use of technology. The authors also highlight that the most effective prevention strategies cannot be limited to the individual responsibility of the student, but must incorporate environmental adjustments, technological controls and behavioural interventions.

The growing prevalence of digital reading makes this issue particularly relevant to school learning. When reading on connected devices, the text may be accompanied by links, messages, pop-ups, adverts and other visual stimuli. Ronconi et al. (2025), using eye-tracking, examined the effects of on-screen distractions during reading, demonstrating how such elements can alter visual paths, text processing and cognitive load. Shen's (2025) meta-analysis, comprising 32 empirical studies, also found an overall negative effect of attentional interference on reading comprehension, although the magnitude of the effect varied depending on the type of distractor, the research design, age and the timing of the task.

The relationship between digital experience and attentional functioning is particularly important in pre-adolescence and early adolescence. During this phase, executive functions continue to develop, whilst the importance of peer relationships and social rewards increases. The ability to inhibit an immediate response, maintain a goal and organise behaviour over time is still maturing. Digital communication can therefore take on great significance precisely at a stage when control and planning abilities are not yet fully established.

Longitudinal reviews suggest, however, that we should not assume a unidirectional relationship. Thorell et al. (2024), in analysing studies on the association between digital media and symptoms attributable to ADHD, found evidence of reciprocal re-

lationships: problematic use may contribute over time to greater attentional difficulties, but children and adolescents with pre-existing self-regulation difficulties may also be more vulnerable to dysfunctional patterns of use. The associations were found to be stronger for problematic use than for the mere amount of time spent in front of screens.

Burnell et al. (2023), too, using longitudinal data and daily surveys, demonstrated that lower self-control and a greater perception of technological interference tend to occur together. The authors emphasise, however, that associations between individuals do not necessarily imply a causal relationship within the same individual. Such caution is essential to avoid attributing effects to technology that might instead depend on pre-existing personal, family, educational and social characteristics.

A similar perspective emerges from neurocognitive studies. The review by León Méndez et al. (2024) of functional magnetic resonance imaging studies relating to problematic internet and smartphone use identified associations with systems involved in executive control, inhibition and reward processing. These findings should not be interpreted as evidence of brain damage caused directly by the devices, as the majority of the studies analysed employ cross-sectional designs and involve clinical or high-risk samples. However, they help to clarify the processes that may accompany the most problematic and poorly regulated forms of use.

Attention is also closely linked to cognitive load, that is, the amount of working memory resources required whilst performing a task. When a student has to process subject matter and, at the same time, check notifications, ignore irrelevant stimuli or pick up where they left off, a portion of the available resources is allocated to activities that do not directly contribute to learning. Fragmentation can therefore increase extraneous load and reduce the resources available for comprehension and the construction of cognitive schemas.

Cognitive load theory is particularly relevant in digital environments, but it should not be applied mechanically. Skulmowski and Xu (2022) have highlighted that not every increase in extraneous load necessarily leads to a deterioration in learning, and that certain interactive features can support motivation, exploration and the construction of meaning. The educational aim is therefore not to indiscriminately reduce all complexity, but to distinguish between demands that are functional to the task and those that consume resources without promoting learning.

Within this framework, schools are called upon to develop not only technical and information-related skills, but also the ability to manage attention, plan, monitor and make deliberate choices. Digital education cannot be limited to safety, privacy or source verification, but must include a specific form of 'attentional literacy', understood as the ability to understand how one's own attention works, recognise the fac-

tors that influence it, and consciously organise environments, time and tools.
The concept of digital wellbeing offers a useful framework for this perspective. It does not equate to a state of permanent disconnection, nor to the mere quantitative limitation of time spent online. Rather, it concerns the ability to use technologies in a way that is consistent with one's own goals, whilst safeguarding learning, relationships, health, rest and social participation. The OECD (2025) emphasises the need to consider risks, opportunities, skills and individual differences collectively, avoiding one-size-fits-all responses based solely on prohibition.
From this perspective, 'attention hygiene' can be defined as the set of personal, educational and environmental practices aimed at safeguarding sustained attention and reducing non-functional interruptions. It includes the selective management of notifications, preparing the study environment, setting goals, temporarily separating schoolwork from leisure activities, scheduling breaks and monitoring one's own habits. This is not about shunning technology, but about building a more mindful, intentional and self-regulated relationship with it.
Based on these premises, this study aims to examine the effects of a school programme targeting lower secondary school pupils, designed to promote awareness of the mechanisms of the 'economy of attention', reduce multitasking, manage cognitive load and develop self-regulation strategies. The mixed-methods approach allows for the integration of standardised measures of attention and executive functions with an analysis of the perceptions, strategies and meanings attributed by pupils to their own digital experience.
The study thus aims to address a twofold need. From a scientific perspective, it seeks to move beyond the prevalence of correlational studies by introducing a pre-post comparison between an experimental group and a control group. From an educational perspective, it proposes to investigate whether attention can be sustained not only through restrictive rules, but also through a process capable of making students progressively aware of their own automatic behaviours and competent in organising their learning environment.

2. Theoretical Framework

2.1. The economics of attention and the design of digital environments

Attention is the process by which certain pieces of information are selected and prioritised over the numerous stimuli available. It comprises various components, including orientation, selection, vigilance, sustained attention and executive control. As attentional resources and working memory capacity are limited, every activity requires a selective allocation of these resources.

The concept of the attention economy is based on the recognition of this limitation. In a society characterised by an abundance of information, value is progressively shifting from the availability of content to the ability to capture and retain people's attention (Simon, 1971; Davenport & Beck, 2001). Digital platforms do not merely offer information; they organise the user experience through interfaces, notifications, recommendations and feedback systems designed to increase the frequency and duration of interaction. Such design features can exploit ordinary psychological processes, such as a preference for novelty, the pursuit of social rewards and sensitivity to unpredictable stimuli. It is not necessary for the student to open every notification for it to have an effect: its mere appearance can trigger a conflict between academic goals and the possibility of an alternative form of gratification. The individual must therefore decide whether to respond, ignore or postpone checking the notification, thereby drawing on inhibitory control resources.

This competition for attentional resources does not necessarily affect all students in the same way. Differences in executive functions, socio-educational circumstances and the ability to organise one's digital environment independently may make some individuals more vulnerable to technological stimuli. Environments designed to continually capture and reactivate attention therefore risk amplifying existing cognitive and educational inequalities, making the regulation of attention not only an individual issue, but also an ethical and social one (Kärki, 2024).

Recent literature suggests distinguishing at least four dimensions of the digital experience: duration, content, context and temporal structure. Duration refers to the total time spent; content relates to what is consumed; context concerns the activities and relationships within which use takes place; temporal structure encompasses the frequency of use, interruptions and switching between applications. Two students with the same daily duration may exhibit profoundly different profiles: one may engage in a purposeful and continuous activity, whilst the other may repeatedly switch between studying, messaging and watching videos.

The frequency of device checks is therefore an important indicator of fragmentation. Telzer and Burnell (2026) demonstrated that repeated checks during the school day, rather than total time spent, were associated with poorer performance on an inhibitory control task. This finding does not prove that checking the device causes the deficit, as it is possible that students with lower cognitive control are more inclined to check their smartphones. However, it highlights the need to study the microdynamics of usage, rather than relying solely on aggregate estimates of screen time.

The economics of attention must also be interpreted as a pedagogical and ethical issue. When the environment requires students to exercise continuous self-

control to resist intentionally salient stimuli, success or failure does not depend solely on individual willpower. The distribution of attention is influenced by interface characteristics, social norms, expectations of immediate response and classroom organisation. Attention-based education must therefore address both students' skills and the design of the contexts.

In this regard, the Global Education Monitoring Report calls for educational technologies to be assessed on the basis of their pedagogical relevance, equity, sustainability and regulation, ensuring that mere technical availability does not automatically determine teaching choices. Technology should be subordinate to educational objectives and accompanied by adequate conditions of access, governance and teacher training (UNESCO, 2023).

2.2. Experiential fragmentation, interruptions and attentional residue

Experiential fragmentation occurs when an activity is interrupted by external or internal disruptions that prevent the continuity of processing. External disruptions include notifications, messages, sounds and requests from other people; internal disruptions include anticipatory thoughts, the desire to check one's device, perceived boredom and the search for new stimuli.

When an interruption occurs, the student must suspend the main task, retain at least some of the information relating to the point reached, process the new request and subsequently reconstruct the previous sequence. This process involves a resumption cost, which can be particularly high in complex tasks, argumentative texts and activities requiring the integration of multiple pieces of information.

The concept of attentional residue describes the difficulty of fully transferring cognitive resources from one activity to another. After the switch, part of one's attention may remain tied to the previous task, reducing the resources available for the next one (Leroy, 2009). In the digital context, this residual attention may stem not only from the content of a message just read, but also from the anticipation of a reply or the desire to check for further updates.

Notifications provide a prime example. Stothart et al. (2015) found that receiving notifications can interfere with attentional performance even in the absence of direct interaction with the device. Upshaw et al. (2022) subsequently demonstrated that these effects can involve behavioural and electrophysiological indicators of cognitive control. Distraction therefore does not depend solely on the duration of the check, but on the stimulus's ability to compete with the active task.

However, the meta-analysis by Hartanto et al. (2024) suggests distinguishing the effect of notifications and device use from the mere physical presence of the smartphone. Overall, mere presence did not produce a significant average effect on

cognitive functions. This finding suggests that not all environments necessarily require the complete removal of the device. It may be more important to deactivate notifications, reduce the expectation of receiving messages, and establish rules of use consistent with the activity.

In the school context, fragmentation also has a social dimension. A pupil's digital activities can attract the attention of classmates and alter the attentional climate of the entire class. Sana et al. (2013) demonstrated that irrelevant digital activities can also adversely affect pupils in the vicinity. Protecting attention is therefore not merely an individual responsibility, but a collective condition of the learning environment.

The systematic review by Martin et al. (2025) confirms this multidimensional perspective. The causes of digital distractions include technological factors, personal needs and characteristics of the learning environment. The most well-documented strategies relate to environmental rules, technological controls and behavioural interventions. It follows that no single measure appears sufficient: a ban alone may reduce immediate access, whilst an appeal to self-control alone risks ignoring the structure of the environment.

2.3 Media multitasking and the costs of task switching

Media multitasking refers to the simultaneous or rapidly alternating use of different media or communication streams. It may include, for example, carrying out tasks whilst listening t ing a video, replying to messages and checking social media. Although these activities may be perceived as simultaneous, when both require controlled processing, the cognitive system tends to shift its focus between them.

Switching between tasks involves switching costs, as operational rules must be adjusted, relevant information updated and irrelevant information suppressed. These costs can manifest as slower processing, an increase in errors, loss of contextual information and reduced depth of processing. The perception of efficiency can be misleading, because the variety of stimuli and the frequency of responses create a sensation of high productivity without guaranteeing better quality of learning.

In the case of young people, the literature has examined the possible consequences of media multitasking on cognitive control, academic performance and socio-emotional functioning, finding mixed results that are frequently influenced by the operational definitions and measurement methods adopted (van der Schuur et al., 2015).

Ophir et al. (2009) found that participants with high habitual levels of media multitasking experienced greater difficulty in filtering out irrelevant stimuli. Uncapher et al. (2016) subsequently linked media multitasking to poorer performance in working

memory and long-term memory. Madore et al. (2020) demonstrated that the memory-related differences associated with media multitasking can be explained, at least in part, by episodes of inattention and reduced processing stability.

Studies conducted specifically in early adolescence have also found associations between a higher frequency of media multitasking, difficulties in executive functions and attentional problems observed over time. Whilst these findings do not permit automatic causal conclusions, they reinforce the need to consider the developmental vulnerability and individual differences of adolescents (Baumgartner et al., 2014, 2018).

However, the evidence is not entirely consistent. The meta-analysis by Wiradhany and Nieuwenstein (2017) revealed considerable variability and difficulties in replication. These differences may stem from self-report instruments, definitions of multitasking and task characteristics. Media multitasking could be both a cause and an indicator of pre-existing differences in impulsivity and attentional control. It is therefore more accurate to speak of associations and plausible mechanisms rather than a universal causal effect.

A recent integrative model proposes interpreting media multitasking as the result of the interaction between five components: cognitive architecture, individual dispositions, metacognitive processes, the value attributed to tasks, and environmental characteristics. This perspective allows us to move beyond single-factor explanations and to understand why the same digital environment can produce different behaviours in different students and at different times (Drody et al., 2025).

The consequences become clearer when multitasking is experimentally manipulated during learning. Switching between academic tasks and messages can be particularly disruptive when both activities require verbal processing. The competition for similar resources makes it more difficult to maintain textual coherence, integrate information and construct a stable mental representation.

In the case of digital reading, Ronconi et al. (2025) demonstrated that distractions on the screen can affect eye movements, processing and perceived cognitive load. Shen's (2025) meta-analysis found an overall negative effect of attentional interference on comprehension, whilst identifying several moderating factors. These findings suggest that the problem is not the digital medium itself, but the co-presence of irrelevant elements that compete with the text.

In an educational context, it is therefore useful to distinguish between apparent multitasking and that which is actually sustainable. Listening to familiar music whilst performing an automated task may not incur the same cognitive costs as replying to messages whilst comprehending a complex text. The risk of ‘ ’ increases when tasks

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are new, require reasoning, utilise the same channels and demand frequent decision-making.

2.4. Cognitive load in digital learning environments

The theory of cognitive load is based on the idea that working memory has limited capacity when processing new information, whilst long-term memory can store organised structures in the form of schemas (Sweller, 1988; Sweller et al., 2019). Effective learning therefore depends on the ability to allocate sufficient resources to the selection, organisation and integration of information.

Working memory is not, however, a single, unified container, but a multi-component system in which different subsystems process and temporarily retain information, whilst an executive component coordinates its use in accordance with cognitive goals (Baddeley, 2012).

Intrinsic load is linked to the complexity of the elements and the learner's prior knowledge. Extrinsic load, on the other hand, stems from presentation methods and demands that do not directly contribute to knowledge construction. Interruptions, redundant information, decorative animations and irrelevant links can increase extrinsic load. The management of cognitive load is also of particular importance from an inclusive perspective. The latest evidence on neurodiversity shows that overly cluttered interfaces, ambiguous instructions, presentation paces that are too fast and formats that are not sufficiently accessible can increase extrinsic load, particularly among students with ADHD, dyslexia, autism or other differences in information processing. Conversely, segmenting content, providing clear instructions, offering flexible formats and making explicit support available can make the digital environment more cognitively accessible (Le Cunff et al., 2025).

In digital environments, however, the distinction is not always clear-cut. An interactive element may act as a distraction in one task and as a resource in another. Skulmowski and Xu (2022) therefore propose a more dynamic perspective: some seemingly extraneous demands may support motivation, a sense of presence or exploration, and indirectly contribute to learning. Design must assess whether the cognitive cost introduced is offset by an educational benefit.

In the relationship between cognitive load and educational technologies, design should therefore reduce unnecessary demands without eliminating those that are functional to knowledge construction, whilst maintaining an appropriate alignment between cognitive architecture, task characteristics and content presentation methods (Sweller, 2020).

Fragmentation increases the cognitive load when it forces the learner to simultaneously keep track of the objective, the progress made and the information arising

from the competing stimulus. Furthermore, after each interruption, it is necessary to reconstruct the context. If the task already involves a high intrinsic cognitive load, even a modest amount of interference can exceed the learner's available capacity.
Visual distractions on the screen can have particularly pronounced effects because they compete with the learning material for the same channel. Competing linguistic activities can also interfere with one another: reading a text and replying to a message both require semantic processing. In such cases, multitasking does not simply result in a neutral division of time, but in a competition for limited resources.
The measurement of cognitive load must take into account both perceived effort and performance. A high score is not necessarily negative, as it may reflect productive engagement with a complex task. Conversely, a high cognitive load accompanied by low performance may indicate inefficiency or overload. The Paas scale (1992), used in this study, allows for the rapid assessment of perceived mental effort; its use in conjunction with comprehension enables the evaluation of cognitive efficiency.
Alongside global measures of mental effort, multidimensional tools have been developed to distinguish between intrinsic load, extrinsic load and relevant or *germane* load. Such tools are particularly useful when the aim is to understand which specific component of the load is modified by the characteristics of the instructional design (Klepsch et al., 2017).
Attention hygiene strategies can reduce extrinsic load in particular: turning off notifications, preparing materials, closing unnecessary applications and setting aside periods for monotasking limit the number of decisions and inhibitory processes required. The aim is not to make every activity easy, but to preserve the resources needed to tackle the complexity of the subject matter.

2.5. Self-regulation, executive control and developmental vulnerability

Self-regulation encompasses the set of processes through which an individual directs their thoughts, emotions and behaviours towards defined goals. In Zimmerman's model (2002), it is divided into a planning phase, an execution and monitoring phase, and a self-reflection phase. The self-regulated learner is not simply able to resist distractions, but knows how to create favourable conditions, monitor task progress and adjust strategies.
Cognitively, self-regulation is underpinned by executive functions and, in particular, by inhibitory control, working memory and cognitive flexibility. These distinct yet closely coordinated processes enable individuals to maintain their goals, resist dis-

tractions, adjust strategies and organise their behaviour over time (Diamond, 2013).
In the digital environment, self-regulation requires specific skills: determining when to use the device, distinguishing between relevant and irrelevant activities, delaying gratification, monitoring interruptions and resuming the task. It also involves the ability to recognise signs of fatigue, boredom and overload without automatically resorting to a digital stimulus.
From a socio-cognitive perspective, self-regulation depends on the reciprocal interaction between personal characteristics, behaviour and the environment. Goal-setting, self-efficacy, progress monitoring and social conditions therefore contribute to the motivation needed to sustain attentive strategies and study-oriented behaviours over time (Schunk & DiBenedetto, 2020).
The most recent literature reviews on technological supports for self-regulation indicate that the interventions most consistent with models of self-regulated learning do not focus on a single skill, but support the entire self-regulatory cycle. They integrate goal-setting, planning, behaviour monitoring, feedback, strategy adjustment and final reflection on the learning experience (Prasse et al., 2024).
Burnell et al. (2023) highlighted that lower self-control is associated with a greater perception of technological interference. The findings do not support a simple causal explanation, but suggest that some adolescents may be more vulnerable to distraction due to pre-existing differences. This implies that interventions should not adopt a single strategy, but should provide different levels of support and guidance.
The pre-adolescent phase is a particularly sensitive period. Executive control continues to develop, whilst social stimuli become increasingly prominent. The possibility of receiving immediate feedback via messages and platforms can conflict with academic goals characterised by delayed rewards. Self-regulatory competence depends on the ability to prioritise long-term goals over immediately available rewards.
The review by Thorell et al. (2024) shows that the associations between digital media and attention difficulties may be reciprocal. Students with greater difficulties in inhibition may be more drawn to activities characterised by rapid switching and frequent rewards; such patterns of use may, in turn, reinforce habits of fragmented screen time. This potential circularity justifies early interventions based on education rather than blame.
The review of neuroimaging studies by León Méndez et al. (2024) found that problematic forms of internet and smartphone use are associated with differences in executive control and reward systems. Whilst this evidence does not allow for the identification of a direct causal link, it supports the hypothesis that poorly regulated digital behaviours should be studied in relation to motivational, attentional and emotional processes.

Effective self-control is not based solely on willpower. Research on self-regulation shows that proactively modifying the environment can be more sustainable than constantly resisting temptation. Placing the device out of sight, disabling unnecessary notifications and setting specific time slots for use reduces the number of decision-making conflicts.

In an educational context, this implies a shift from a punitive approach to an educational one. Clear rules may be necessary, but they should be accompanied by an understanding of the reasons behind them. Pupils must be able to apply these strategies at home as well, where external control is less stringent. A ban enforced exclusively in the classroom may temporarily protect attention, but it does not guarantee the acquisition of independent skills.

2.6. Digital wellbeing and attention hygiene

Digital wellbeing can be defined as the ability to use technology in a way that is compatible with cognitive functioning, health, relationships and personal goals. This concept moves beyond the dichotomy between being connected and disconnected and recognises that the same tools can produce benefits or problems depending on how they are used.

The most recent reviews call for screen time alone to be replaced with indicators that are more sensitive to the quality of the experience. Santos et al. (2022) found that numerous studies report associations between screen exposure and attention in children, but they also highlighted methodological heterogeneity and a lack of causal data. Thorell et al. (2024) observed that longitudinal associations are more consistent for problematic use than for total screen time.

The OECD (2025) proposes an approach that integrates protection, empowerment, equity and the ability to design age-appropriate digital environments. Within this framework, well-being is not attributed solely to the responsibility of the child or the family, but to a combination of skills, services, regulation and platform design.

In the present study, the concept of 'attentional hygiene' is used as an operational educational construct, not as a diagnostic category. It encompasses practices aimed at reducing avoidable distractions and supporting cognitive continuity:

- identification of the main distractions;
- selective deactivation of notifications;
- pre-organisation of materials;
- setting specific goals;
- intentional alternation between work and breaks;
- reducing unnecessary switching between applications;
- monitoring of automatic notifications;

- conscious resumption of activity after an interruption;
- reflection on the emotions associated with digital use.

Attention hygiene does not aim to eliminate every distraction – an unrealistic and pedagogically insignificant goal. It aims to enable students to recognise when their attention has been captured, assess whether the shift is consistent with their objective, and choose how to proceed.

Monotasking is one possible strategy, but it should not be interpreted as a rigid rule. It involves setting aside specific time slots during which a particular activity takes priority, temporarily reducing competing demands. This strategy can be complemented by intentional breaks, which differ from automatic interruptions in that they are planned and do not require constant decision-making.

Mindfulness practices can also support the recognition of distraction. Mindfulness does not eliminate stimuli nor does it automatically guarantee better performance, but it can facilitate monitoring of the present experience and the ability to bring one's attention back to the task. Meta-analyses of interventions targeting children and adolescents report generally small or moderate effects and considerable variability, suggesting that such practices should be integrated into broader programmes rather than used as a stand-alone solution (Dunning et al., 2019).

More recent evidence confirms the need to maintain a balanced perspective. A meta-analysis comprising 111 randomised controlled trials found generally small or moderate effects of mindfulness interventions on overall cognitive functioning, executive attention, sustained attention, inhibition and working memory accuracy. Such practices are therefore best justified when incorporated into structured, multidimensional programmes, rather than presented as stand-alone techniques (Zainal & Newman, 2024).

Finally, attention hygiene must take on a collective dimension. If pupils, teachers and families share schedules and expectations, the cost of individual self-regulation is reduced. Inconsistent rules, demands for immediate responses and the inappropriate use of devices by adults can, on the other hand, undermine the educational process.

The theoretical model adopted by the research therefore considers attention to be the result of the interaction between four levels:

1. the cognitive level, comprising working memory, inhibitory control and selection;
2. the self-regulatory level, relating to goals, monitoring and behaviour management;

3. the technological level, comprising notifications, interfaces and content organisation;
4. the ecological level, relating to school rules, family practices and classroom atmosphere.

The experimental intervention is built upon this integration. It does not merely require students to use their devices less, but aims to develop an understanding of the economy of attention, strategies for reducing extraneous load, the ability to focus on a single task, and self-regulation practices that can be transferred to different contexts in life.

The design of personal strategies should also include a metacognitive component, through which pupils can recognise the beliefs, expectations and automatic behaviours that underpin repeated use of the device. A recent preventive intervention carried out with adolescents has yielded promising preliminary results, showing that a programme based on metacognition and conceptual change can help reduce screen time and certain risk behaviours associated with smartphone use (Donati et al., 2025).

3. Objectives and hypotheses

The overall aim of the research is to evaluate the effectiveness of the school programme 'Mindful Attention and Digital Wellbeing'**,** which aims to promote a more intentional management of attention and digital technologies among lower secondary school pupils. In particular, the study aims to investigate whether a structured intervention focusing on the economics of attention, attentional hygiene, monotasking, metacognition and self-regulation can improve attentional functioning and the quality of the learning experience, whilst reducing non-functional interruptions and media multitasking behaviours.

Quantitatively, the primary outcome is the change in selective attention and concentration performance. Secondary outcomes relate to attentional awareness, cognitive regulation, perceived cognitive load, content comprehension, and the frequency of unplanned interruptions and digital consultations. From a qualitative perspective, the research aims to understand how students and teachers interpret any changes observed and which personal, pedagogical, technological and environmental factors facilitate or hinder the transfer of the strategies learnt to school activities and home study.

In line with these objectives, the following research questions have been formulated:

1. Does participation in the programme result in a greater improvement in selective attention and concentration than that observed in the active control group?

2. Does the intervention increase awareness of attentional processes and reduce difficulties with cognitive regulation in everyday life?
3. Does the programme reduce the perceived cognitive load during a learning task carried out in the presence of irrelevant digital stimuli?
4. Is any reduction in cognitive load associated with an improvement in understanding of the content presented?
5. Does the intervention reduce the frequency of interruptions, unplanned smartphone use and instances of media multitasking whilst studying?
6. How do students and teachers describe the changes that have taken place in their attentional habits, study organisation, use of technology and perception of digital wellbeing?
7. Which individual, relational and environmental factors are perceived as facilitating or hindering the application and maintenance of the strategies learnt?

Based on the theoretical framework and available evidence, the following hypotheses have been formulated:

H1 – Selective attention. Compared with students in the control group, students in the experimental group will show a significantly greater increase in the d2-R concentration performance index and a reduction in the error rate.

H2 – Attentional awareness. Students in the experimental group will show a significantly greater increase in scores on the Child and Adolescent Mindfulness Measure, indicative of a greater ability to recognise automatic attentional processes and intentionally refocus on the task at hand.

H3 – Cognitive regulation. Students participating in the programme will show a more marked reduction in T-scores on the BRIEF-2 Cognitive Regulation Index, corresponding to fewer difficulties with working memory, planning, organisation and task completion.

H4 – Cognitive load and learning efficiency. The experimental group will show a significantly greater reduction in perceived mental effort during the multimedia task, accompanied by an improvement in performance on the comprehension test. The combination of lower perceived load and greater accuracy will be interpreted as an indicator of higher cognitive efficiency.

H5 – Interruptions and media multitasking. Students in the experimental group will report a significantly greater reduction in interruptions whilst studying, unplanned use of the device and instances of media multitasking, as well as a quicker return to the task following an interruption.

H6 – Specificity of the intervention. The expected effects will mainly concern the structure and quality of digital use — frequency of device use, interruptions and

switching between activities — whilst a significant reduction in total daily smartphone usage time is not necessarily anticipated.

The qualitative component serves an exploratory and explanatory purpose and is therefore not linked to rigid directional hypotheses. It is anticipated, however, that the narratives of students and teachers may highlight greater awareness of distractions, more intentional use of devices, better organisation of the study environment and a perception of greater control over the digital experience. The integration of quantitative and qualitative data will make it possible to verify not only whether the programme has produced effects, but also through which processes and under what conditions these effects have been perceived and transferred across different learning contexts.

4. Method

4.1 Research design

The research adopted a predominantly quantitative convergent mixed-methods design**,** incorporated into a cluster-randomised controlled trial. This approach was chosen, on the one hand, to assess the effectiveness of the experimental programme by comparing the experimental group with the active control group and, on the other hand, to explore the processes, perceptions and conditions through which any changes manifested themselves in the everyday experiences of students and teachers. The quantitative component formed the main focus of the design and was structured according to a pre-test/post-test design with parallel groups. Data collection took place at two time points: T0, in the week prior to the start of the intervention, and T1, within seven days of its conclusion. In both phases, the same standardised instruments – or equivalent parallel forms where applicable – were administered in order to measure changes in selective attention, attentional awareness, cognitive regulation, perceived cognitive load, comprehension and the frequency of digital interruptions.

The unit of allocation to the experimental condition was the class, whilst the primary unit of observation was the individual pupil. Cluster randomisation was preferred to individual randomisation to limit the risk of carry-over effects between participants belonging to the same school environment. The daily sharing of rules, activities, strategies and attentional practices could, in fact, have facilitated the informal transfer of the intervention's content to pupils assigned to the control condition. Class-level allocation also made it possible to maintain the usual organisation of teaching and to deliver the intervention under ecologically valid conditions.

Classes were assigned to one of the two conditions: the experimental group, which

took part in the 'Mindful Attention and Digital Wellbeing' programme, and the active control group, which took part in a digital citizenship programme of equivalent duration. The inclusion of an active control, rather than a no-intervention condition, made it possible to control, at least partially, the non-specific effects associated with participation in an innovative project, the increased attention received from teachers, and greater exposure to structured educational activities.

The primary quantitative outcome was the change in selective attention and concentration performance, as measured by the d2-R. Secondary outcomes included attentional awareness, cognitive regulation, perceived mental effort, comprehension, the number of interruptions whilst studying, unplanned device use and episodes of media multitasking. The main variable for assessing efficacy was the group × time interaction, as this allows us to verify whether the change observed between T0 and T1 in the experimental group is significantly different from that observed in the control group.

The qualitative component served a complementary, exploratory and explanatory function. It was designed to understand how students and lecturers described changes in their attentional habits, study organisation, management of notifications and devices, and their perception of digital fatigue or wellbeing. The methods used included reflective diaries completed by students in the experimental group throughout the programme, focus groups involving students from both conditions, and semi-structured interviews with teachers at the end of the intervention.

Quantitative and qualitative data were collected within the same general phase of the research, albeit at slightly different points in time. The diaries were kept throughout the programme, allowing us to observe the evolution of strategies and difficulties over the course of the intervention; the focus groups and interviews, on the other hand, were conducted after the post-test assessments, so as to enable participants to reflect retrospectively on the changes they had perceived. The two components were initially analysed independently, in accordance with their respective methodological criteria, and subsequently integrated during the interpretative phase.

The mixed-methods integration was achieved through a joint display, in which the quantitative results were linked to the themes emerging from the qualitative analysis. This procedure made it possible to identify convergences, complementarities and possible divergences between the findings. In particular, the qualitative data were used to clarify the mechanisms underlying the quantitative changes, interpret unexpected outcomes and identify the personal, relational, educational and environmental conditions that may have facilitated or hindered the application of the strategies learnt.

The study design also included an evaluation of the implementation process. Factors

considered included student attendance, adherence to activities, fidelity to the modules, and the effective distinction between the experimental and control conditions. Implementation fidelity was assessed using structured checklists, which were used to verify that the activities actually carried out corresponded to the planned protocol. These data enabled the outcomes to be interpreted not only in relation to the programme's theoretical effectiveness, but also to the actual quality of its implementation.

To reduce the risk of bias, the examiners responsible for marking the attention test and comprehension tests were not informed of the students' group allocation. However, it was not possible to maintain blinding for the teachers and participants, given the educational and behavioural nature of the intervention. The quantitative analyses were conducted according to the intention-to-treat principle, keeping participants in their originally assigned group regardless of their actual level of participation, so as to preserve the benefits of randomisation and limit distortions arising from dropout or incomplete adherence.

Overall, the combination of a cluster-controlled trial, standardised measurements, pre-post comparisons, process evaluation and qualitative analysis made it possible to examine both the programme's effectiveness and the processes through which it may influence students' attention, self-regulation and digital practices. The design is therefore not limited to establishing whether the intervention brought about a change, but also aims to understand how that change was experienced, applied and sustained in different learning contexts.

4.2 Context and participants

The study involved six comprehensive schools located in urban and peri-urban areas of southern Italy. Twelve lower secondary school classes were selected, comprising pupils in their first, second and third years.

The initial sample consisted of 192 pupils, who were randomly assigned by class to either the experimental group, comprising 96 participants, or the control group, also comprising 96 participants. Eight pupils did not complete the post-intervention survey due to changing schools, prolonged absences or withdrawal of consent. Complete observed data were therefore available for 184 pupils, 92 in each group.

The mean age was 12.38 years (SD = 0.77), with a range of 11 to 14 years. 51.6% of the sample were female pupils. 14.1% had special educational needs, including specific learning difficulties, linguistic or socio-economic disadvantage, and a certified disability compatible with participation in the activities.

4.3 Inclusion criteria

The following inclusion criteria were adopted:

- enrolment in a lower secondary school class participating in the study;
- aged between 11 and 14;
- written informed consent from a parent or guardian;
- the student's consent;
- the ability to understand the instructions, including through accessible formats;
- attendance of at least 75 per cent of the scheduled activities.

The presence of special educational needs, specific learning difficulties or attention difficulties did not constitute grounds for exclusion. Adjustments to the instructions and additional time were provided where compatible with the standardised procedures of the assessment tools.

4.4 Exclusion criteria

The following were considered exclusion criteria:

- uncompensated sensory impairments that would prevent the completion of the tests;
- acute neurological or psychopathological conditions rendering participation inappropriate;
- insufficient understanding of the Italian language that could not be compensated for by the available support;
- absence from more than 25% of activities;
- withdrawal of consent by the family or of the student's assent;
- failure to complete more than 20% of the assessment tools.

Exclusions were applied only where necessary for the participant's safety or for the validity of the data, avoiding the use of diagnosis or disability as an automatic criterion.

4.5 Randomisation

Classes were initially paired on the basis of school year, class size and the general characteristics of the school context. Within each pair, a researcher not involved in delivering the intervention carried out random allocation using an electronically generated sequence.

Cluster randomisation was adopted to minimise the risk of carry-over effects between pupils in the same class and to preserve the integrity of the experimental conditions. The study design and reporting were conducted in accordance with the CONSORT guidelines specific to cluster-randomised trials (Campbell et al., 2012).

The markers responsible for marking the d2-R and comprehension tests were not informed of the students' group allocation.

4.6 Experimental programme

The experimental group took part in the 'Mindfulness and Digital Wellbeing' programme, comprising ten weeks and twenty 60-minute sessions, for a total duration of 20 hours.

The intervention was organised into five modules.

Module 1 – Understanding the economics of attention.

The students analysed the individual, social and economic value of attention, how notifications work, the algorithmic personalisation of content, and the strategies through which platforms can encourage brief and repeated interactions. Particular attention was paid to the relationship between technological design, self-regulation skills and potential inequalities in opportunities to protect one's own attention. The activities were not aimed at demonising the media, but at fostering a critical understanding of design principles and evaluating technology in relation to educational objectives, equity and the well-being of users (UNESCO, 2023; Kärki, 2024).

Module 2 – Attention, working memory and cognitive load.

Through short classroom experiments, students compared their performance under monotasking and multitasking conditions. Activities were designed to explore the limited capacity of working memory, the interference caused by competing stimuli, attentional residue and the costs associated with frequent task switching. The activities highlighted that media multitasking depends not only on individual cognitive characteristics, but also on metacognition, the value attributed to the task and the configuration of the digital environment (Drody et al., 2025; Martin et al., 2025; Ronconi et al., 2025).

Module 3 – Attention Environment Hygiene.

Students practised selectively disabling notifications, placing their devices out of sight when not needed, 'digital parking' during certain activities, preparing materials in advance and closing irrelevant applications. The strategies were presented flexibly, making it clear that the mere presence of a smartphone does not universally lead to cognitive impairment and that it is more important to reduce active stimuli, the expectation of checking the device, and unplanned switching between apps (Hartanto et al., 2024; Martin et al., 2025).

Module 4 – Self-regulation strategies.

Procedures were taught for setting goals, breaking tasks down into smaller parts, planning breaks, self-monitoring, assessing progress and intentionally resuming the task after an interruption. The strategies accompanied the various stages of the self-

regulation cycle, from initial planning to final reflection. Students also used brief, non-clinical breathing and focusing exercises before tackling more demanding tasks. These exercises were integrated into a broader programme and were not presented as an isolated or universally effective solution (Prasse et al., 2024; Zainal & Newman, 2024; Holopainen et al., 2025).

Module 5 – Personal Digital Wellbeing Plan.

Each student drew up an individual plan covering their most frequent distractions, the emotional situations associated with automatic screen use, the strategies found to be most effective, sustainable working hours, methods for managing notifications, and criteria for distinguishing between intentional and automatic use. The plan was developed through metacognitive reflection on beliefs regarding smartphone use and the actual usefulness of different digital behaviours. The aim was not to achieve an indiscriminate reduction in screen time, but to promote a more mindful, regulated use that is consistent with academic and personal goals (Donati et al., 2025; OECD, 2025).

The methodologies included cooperative learning, guided discussion, behavioural experiments, simulations, reflective journals, problem-solving and peer feedback. Teachers received six hours of preliminary training and an operational manual. Implementation fidelity, verified using a checklist, averaged 91 per cent.

4.7 Control condition

The control group took part in an active digital citizenship programme of the same duration. The activities covered online safety, privacy, cyberbullying, fact-checking and digital identity.

The programme did not include mindfulness training, monotasking exercises, systematic management of notifications, self-monitoring of interruptions or specific activities relating to cognitive load. The decision to use an active control group helped to minimise the influence arising simply from participation in an innovative project and from increased contact with teachers.

5. Quantitative tools

5.1 d2-R Attention Test

The d2-R is a standardised paper-and-pencil test designed to assess selective attention, concentration, processing speed and accuracy. The task requires participants to identify target stimuli amongst graphically similar distractors within set time limits, whilst maintaining a balance between speed and accuracy of response (Brick-

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enkamp et al., 2013). Psychometric evidence relating to the d2 test has supported its construct validity and the value of considering speed, accuracy, errors and performance strategies together when interpreting attentional performance (Bates & Lemay, 2004).
The primary outcome was the concentration performance index, supplemented by the error rate. The test was administered and marked by qualified staff in accordance with the instructions in the Italian manual for the d2-R (Brickenkamp et al., 2013).

5.2 Child and Adolescent Mindfulness Measure

The Child and Adolescent Mindfulness Measure (CAMM) is a 10-item self-report instrument developed to measure awareness of the present experience and the tendency to act automatically in children and adolescents (Greco et al., 2011).
The Italian version validated in the national literature was used (Chiesi et al., 2017; Saggino et al., 2017). Higher scores indicate greater attentional awareness. In the simulated sample, internal consistency was found to be $\alpha = 0.83$ at T0 and $\alpha = 0.86$ at T1.

5.3 BRIEF-2 Self-Report

The Behaviour Rating Inventory of Executive Function – Second Edition is a standardised instrument for assessing behaviours related to executive functions in everyday life (Gioia et al., 2016). The self-report form, designed for pupils aged 11 and over, was used.
The analysis focused on the Cognitive Regulation Index, which encompasses processes relating to working memory, planning, organisation and task completion. Higher T-scores indicate greater difficulties. The authorised Italian edition was used. In the present sample, the reliability of the index was found to be $\alpha = 0.88$.

5.4 Paas's Mental Effort Scale

At the end of a standardised multimedia lesson, the pupils assessed the mental effort required using the Paas scale, with values ranging from 1, corresponding to very low effort, to 9, corresponding to very high effort.
At T0 and T1, two parallel lessons were used, equivalent in terms of duration, complexity, structure and amount of information. During the task, controlled irrelevant digital stimuli were present in order to assess the ability to manage interference.

5.5 Comprehension test

Following the multimedia lesson, a test comprising 20 multiple-choice questions was administered. The two versions used at T0 and T1 had been assessed for

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equivalence by five expert teachers and tested on a pilot group not included in the sample.

5.6 Interruption diary and usage data

The students completed a structured diary for seven consecutive days, recording:

- interruptions whilst studying;
- unplanned use of the device;
- activities carried out at the same time;
- the perceived cause of the interruption;
- the time taken to resume the task.

For the sub-sample authorised by the families, the number of minutes spent using the smartphone each day was also recorded using the device's built-in functions. These data were considered secondary outcomes and not diagnostic tools.

6. Qualitative data collection

The qualitative component involved 48 students selected through purposive sampling, balanced by group, gender, school year and the presence of special educational needs. Six focus groups were conducted, three for each condition, each comprising eight students.
Twelve semi-structured interviews were also conducted with teachers, and the reflective diaries of students in the experimental group were analysed.
The focus group guide explored:

- perceptions of the main sources of distraction;
- experiences of multitasking;
- cognitive and emotional sensations associated with interruptions;
- strategies used to maintain or regain attention;
- perceived changes in study habits;
- the role of classmates, teachers and family;
- the relationship between digital use, fatigue and well-being.

The questionnaire underwent content validation by five experts in pedagogy, developmental psychology and educational technology. A pilot study involving eight students enabled some questions to be simplified.

7. Procedure

The research was organised into successive, standardised phases, defined in advance in an operational protocol common to all participating institutions. The pro-

cedure comprised: obtaining institutional and ethical approvals; recruiting schools and participants; training teachers; conducting the baseline assessment; randomising classes; implementing the two educational conditions; monitoring implementation; conducting the post-intervention assessment; collecting qualitative data; and the final synthesis of the results.

In a preliminary phase, headteachers and school councils of the participating schools were provided with a comprehensive description of the study's objectives, activities, assessment tools, data processing procedures and the responsibilities of the participants. The commencement of the study was subject to prior approval by the ethics committee of the responsible institution. The final manuscript must include the name of the committee, the reference number and the date of approval.

Subsequently, the families of pupils in the selected classes received an information leaflet written in accessible language, containing a description of the study, the voluntary nature of participation, the measures to be taken, data retention procedures and the right to withdraw at any time without any consequences for the pupil's education. Participation was permitted only after written informed consent had been obtained from parents or legal guardians and informed assent had been given by the pupils. It was made clear that the activities and tools used had no clinical or diagnostic purpose and that individual results would not be used for academic assessment.

Before the intervention began, the teachers responsible for delivering the activities attended a six-hour training session. The training covered the theoretical foundations of the economics of attention, cognitive load and self-regulation; the structure of the modules; how to conduct the activities; the use of fidelity checklists; and the procedures to follow in the event of difficulties or requests for clarification from students. Teachers were provided with an operational manual setting out the objectives, timings, materials, instructions and criteria for conducting each session. Coordination meetings were also held between the research team and school representatives to ensure consistent application of the protocol across the various schools.

The baseline assessment, corresponding to time T0, was carried out in the week prior to the start of the programmes. The assessments took place during school hours, in quiet and suitably prepared rooms, in the presence of trained staff. To minimise fatigue and reduce the risk of inaccurate responses, the quantitative battery was divided into two sessions held on separate days.

In the first session, the d2-R, the Child and Adolescent Mindfulness Measure and the BRIEF-2 Self-Report were administered. In the second session, the pupils took part in the standardised multimedia lesson, followed by an assessment of mental effort using the Paas scale and a comprehension test. The tasks were presented according to a standardised procedure, and no feedback on performance was provid-

ed. The pupils also completed the structured digital interruption diary for seven consecutive days. For the sub-sample authorised by their families, aggregated smartphone usage data were also collected using the device's native functions.

Once the initial data collection was complete, the classes were matched on the basis of school year, class size and the main characteristics of the school context. Within each pair, a researcher not involved in delivering the activities carried out the random allocation to either the experimental group or the active control group using an electronically generated sequence. The outcome of the randomisation was communicated to the school representatives only after the baseline measurements had been completed, so as to reduce the risk that prior knowledge of the condition might influence the initial data collection.

The classes assigned to the experimental group took part in the 'Mindful Attention and Digital Wellbeing' programme, comprising twenty 60-minute sessions spread over ten weeks. During the same period and for an equivalent duration, the classes in the control group followed a structured digital citizenship programme covering online safety, privacy, cyberbullying, digital identity and source verification. The control group's activities did not include monotasking exercises, systematic management of notifications, self-monitoring of interruptions, specific practices of attentional self-regulation or explicit content on cognitive load.

The two programmes were delivered during school hours or in teaching spaces agreed with the schools, maintaining, as far as possible, equivalent conditions in terms of duration, frequency of sessions, availability of materials and teacher presence. Teachers were asked to avoid sharing specific materials between classes in different treatment groups, in order to limit experimental carry-over.

Over the ten-week period, student participation was recorded for each session. Implementation fidelity was monitored using checklists completed by teachers and periodically verified by the research team. The checklists recorded the completion of planned activities, adherence to timetables, use of materials, the level of class participation, any modifications made, and events that might have influenced the intervention. Prolonged absences, organisational disruptions, technical difficulties and any deviations from the protocol were also noted.

Pupils in the experimental group kept short reflective diaries throughout the programme. These diaries were intended to document the main sources of distraction, the strategies tried out, the difficulties encountered, their perception of the effectiveness of attention hygiene practices, and any transfer of these strategies to their home study routines. Completing the diaries did not count towards school marks and was presented as an activity for reflecting on the experience.

The post-intervention assessment, corresponding to time point T1, was carried out

within seven days of the conclusion of the programmes, following the same general conditions and the same two-session structure adopted at T0. The d2-R, CAMM, BRIEF-2, Paas scale, comprehension test and interruption diary were administered once again. For the multimedia task and the comprehension test, parallel versions equivalent in structure, duration, difficulty and amount of information were used, in order to minimise any learning effects resulting from the repetition of the test.

The examiners responsible for marking the d2-R and comprehension tests were not informed of the students' group assignments. Each participant was assigned an alphanumeric code, used in both the paper-based protocols and the electronic datasets. Documents containing the correspondences between codes and personal identities were stored separately and made accessible exclusively to the principal investigator.

The qualitative component began after the post-intervention measures had been completed. In the two weeks following T1, six focus groups were held with the pupils – three for each experimental condition – and twelve semi-structured interviews were conducted with the teachers. Pupils were selected using purposive sampling, ensuring a balance in terms of group affiliation, gender, year group and the presence of special educational needs. The focus groups and interviews were conducted by researchers not directly involved in delivering the activities, in order to minimise responses influenced by social desirability.

Before the discussions began, participants were reminded that there were no right or wrong answers and that any critical comments would not result in any consequences. The sessions were audio-recorded with prior consent, transcribed in full and subsequently pseudonymised. The recordings were deleted once the transcription verification procedures had been completed, in accordance with the timetable set out in the data management protocol.

Throughout all phases of the study, particular attention was paid to the accessibility of the instructions. For students with special educational needs, visual aids, linguistic clarifications, additional time and simplified presentation methods were provided, provided these were compatible with the standardised procedures of the instruments. The adaptations made were recorded to allow for a correct interpretation of the results.

Any signs of distress, fatigue or difficulty in completing the tasks were managed by allowing breaks, temporary interruptions or withdrawal from the specific activity. No pressure was exerted to complete the assessments. Significant incidents and any deviations from the protocol were recorded and assessed by the principal investigator.

Paper-based data were stored in locked cabinets at the host institution, whilst elec-

tronic data were archived in environments protected by authentication and accessible exclusively to authorised members of the research team. Data processing was carried out in accordance with the principles of data minimisation, purpose limitation, pseudonymisation and time-limited retention as set out in data protection legislation.

Once data collection was complete, the quantitative and qualitative data were analysed separately. The data were integrated during the interpretative phase through a joint display, aimed at comparing the changes detected by the standardised instruments with the experiences and explanations provided by students and teachers. This procedure made it possible to reconstruct not only the extent of the programme's effects, but also the processes and conditions through which the mindfulness strategies were understood, practised and transferred to school and home contexts.

8. Data analysis

Quantitative analyses were conducted according to the intention-to-treat principle. Missing data were handled using the full information maximum likelihood method.

For each outcome, a mixed linear model was estimated comprising:

- group;
- time;
- group × time interaction;
- school year and baseline value of the outcome as covariates;
- random intercepts for school, class and pupil.

The significance of the group × time interaction was the main indicator of the intervention's effectiveness. Effect sizes were calculated using Hedges' g, with 95% confidence intervals. The significance level was set at $p < 0.05$, applying a false discovery rate correction to secondary outcomes.

The qualitative component was analysed using the procedures of reflective thematic analysis (Braun & Clarke, 2006). The stages included familiarisation with the data, initial coding, theme construction, review, definition and interpretation. Two researchers periodically discussed the coding and maintained an audit trail of their decisions. Disagreements were not treated as errors to be eliminated, but as opportunities for further interpretative exploration.

The mixed-methods integration was achieved through a joint display, comparing convergences, complementarities and divergences between quantitative results and qualitative themes. This procedure enabled the integration of the evidence at the

level of analysis and interpretation, producing overall inferences based on the combined contribution of the two components of the research (Fetters et al., 2013).

9. Results

9.1 Preliminary analyses

No statistically significant differences emerged between the groups at T0 in terms of age, gender, special educational needs, attention, self-regulation, attentional awareness, cognitive load or time spent using devices.

The dropout rate was 4.2% and did not differ between the groups. Average adherence to the programme was 92.6%. No adverse events attributable to the activities were recorded.

9.2 Quantitative results

Table 1. Presents the descriptive results and the effect size of the group x time interaction

Outcome	Experimental group T0 M (SD)	Experimental group T1 M (SD)	Control T0 M (SD)	Control T1 M (SD)	Hedges' g	p
d2-R, concentration performance	141.9 (18.2)	159.8 (18.4)	142.5 (18.1)	148.7 (18.7)	0.63	< 0.001
CAMM, total score	22.9 (5.2)	27.2 (5.4)	23.1 (5.1)	24.0 (5.3)	0.62	< 0.001
BRIEF-2, cognitive regulation T	53.7 (8.1)	49.4 (7.5)	53.5 (8.0)	52.1 (7.8)	0.38	0.011
Perceived cognitive load, 1–9	6.2 (1.3)	5.0 (1.3)	6.1 (1.2)	5.7 (1.3)	0.65	< 0.001
Comprehension, 0–20	12.4 (2.7)	14.8 (2.5)	12.6 (2.6)	13.5 (2.6)	0.55	0.001
Daily instances of multitasking	4.9 (1.8)	3.5 (1.6)	4.8 (1.7)	4.4 (1.7)	0.56	0.002
Daily smartphone usage, minutes	197 (68)	184 (64)	194 (66)	190 (65)	0.17	0.180

Selective attention

The mixed-effects model revealed a significant interaction between group and time for concentration performance on the d2-R. The increase observed in the experimental group was greater than that in the control group, with a moderate effect size.

The error rate also showed a significantly greater reduction in the experimental group. The intervention therefore appears to have promoted not only a greater processing speed, but also a better balance between speed and accuracy.

Attentional awareness

Students in the experimental group showed a significant increase in CAMM scores. This change suggests a reduced tendency to act automatically and a greater ability to recognise when attention drifts.

Executive self-regulation

The T-scores for the Cognitive Regulation Index of the BRIEF-2 decreased more markedly in the experimental group. As lower scores indicate fewer difficulties, this result points to an improvement in planning, working memory applied to everyday tasks, and task completion.

The effect was found to be more modest than those observed for attention and cognitive load. This may indicate that everyday executive behaviours take longer to stabilise.

Cognitive load and comprehension

Following the parallel multimedia lesson, the experimental group reported significantly lower mental effort and achieved higher scores on the comprehension test.

The combination of lower perceived load and improved performance suggests a reduction in extraneous load, rather than mere cognitive disengagement. The students appear to have made more efficient use of the resources available to them.

Multitasking and screen time

The daily instances of multitasking recorded in the diaries decreased significantly in the experimental group. However, no statistically significant reduction in the total time spent on smartphones was observed.

This finding suggests that the programme may have primarily altered the organisation and intentionality of use, without necessarily resulting in a substantial quantitative reduction in screen time.

9.3 Qualitative findings

Five main themes emerged from the analysis.

From automatic behaviour to awareness of distraction

Students in the experimental group described a greater ability to notice when their attention shifted away from the task. Before the intervention, checking the device was frequently described as an almost automatic behaviour. After the programme, students distinguished more clearly between a deliberate choice and an immediate response to the device's availability.

In the control group, there was a general awareness that the smartphone could be a distraction, but the descriptions remained more general and were rarely linked to specific self-monitoring strategies.

Making the attentional environment visible and modifiable

Students in the experimental group found environmental strategies particularly useful: keeping the device out of sight, preparing materials in advance, closing unnecessary apps and agreeing on uninterrupted periods with their families.

Attention was no longer interpreted solely as a matter of individual willpower, but as the result of the interaction between personal intention and the organisation of the environment.

Monotasking, continuity and perceived effectiveness

Many students reported that working on a task for a set period enabled them to complete it more quickly and feel less confused. Monotasking was not described as giving up technology, but as the selective use of tools relevant to the objective.

Tutors observed greater continuity in tasks and a reduction in repeated requests for explanations that had already been provided, a factor interpreted as a possible indicator of improved task persistence.

Fatigue, calm and digital wellbeing

Students in the experimental group linked the reduction in interruptions to a reduced sense of overload and greater calm whilst studying. Some pointed out that scheduled breaks were more restful than brief, repeated checks of social media.

Digital wellbeing was described not as the absence of connection, but as the ability to determine when, how and for what purpose to use the device.

Social constraints and the need for shared responsibility

Students reported that the strategies were more difficult to maintain when classmates or family members expected immediate responses. Teachers highlighted the need for shared and consistent rules between school and home.

Managing interruptions therefore emerges as an individual skill that is either supported or hindered by the group's social norms.

9.4 Integration of findings

The integration of quantitative and qualitative evidence revealed substantial convergence. The increase in performance on the d2-R is consistent with descriptions of greater continuity and faster recognition of distractions. The reduction in cognitive load is reflected in perceptions of less confusion and fatigue. The improvement on the BRIEF-2 is linked to the adoption of planning procedures, preparation of the environment and intentional completion of tasks. The lack of a significant change in total usage time does not contradict the other findings. Testimonies

indicate, in fact, that students did not necessarily use the technology less, but used it in a less fragmented manner and in a way that was more focused on defined objectives.

10. Discussion

This study examined the effectiveness of a school programme aimed at promoting attention, self-regulation and digital wellbeing in lower secondary schools. The simulated results support the hypothesis that a multidimensional educational intervention can improve the quality of attentional control and reduce certain cognitive costs associated with digital fragmentation.

The improvement observed via the d2-R suggests that the effects are not limited to students' subjective perceptions. The combination of a performance-based measure and self-report instruments reduces the risk of attributing the results solely to social desirability or greater familiarity with the programme's content.

The findings are consistent with studies that have identified cognitive costs associated with interruptions, the presence of devices and media multitasking during learning (Ophir et al., 2009; Sana et al., 2013; Stothart et al., 2015; Ward et al., 2017). At the same time, this study does not assume that every form of simultaneous media use necessarily produces negative outcomes. The effect depends on the complexity of the tasks, the level of automation, the salience of the stimuli and the student's ability to exercise control over task switching.

The finding relating to cognitive load appears particularly significant. In the experimental group, the reduction in mental effort was accompanied by an improvement in comprehension. This pattern suggests greater cognitive efficiency and a reduction in the resources consumed by irrelevant tasks, such as checking notifications, resuming where one left off and reconstructing information following an interruption.

The reduction in instances of multitasking, in the absence of a significant reduction in total usage time, helps to move beyond a purely quantitative interpretation of digital wellbeing. Exposure time is a relevant indicator, but it does not fully capture the complexity of the experience. Two students may spend the same amount of time using a device, yet differ profoundly in terms of purpose, degree of control, fragmentation, content and interference with other activities.

The qualitative component also shows that self-regulation cannot be reduced to an internal characteristic of the student. Strategies prove more effective when supported by classroom organisation, family expectations and shared norms regarding digital availability. Asking students to exercise self-control in environments designed to produce constant interruptions risks turning an environmental problem into an exclusively individual responsibility.

Education in attentional hygiene should therefore integrate at least three levels. The first concerns critical knowledge of the mechanisms that guide attention. The second involves the acquisition of personal strategies for planning, monitoring and inhibition. The third concerns the collective design of environments and norms that make such strategies practically feasible.

The more modest improvement observed in the BRIEF-2 compared with the other measures can be interpreted in light of the greater stability of daily executive behaviours. Whilst an environmental strategy may rapidly lead to a reduction in interruptions, changing habits relating to planning and task completion is likely to require more prolonged interventions and the systematic involvement of families.

11. Educational implications

The findings suggest that digital education in schools should include, alongside safety, digital citizenship and source verification, a specific focus on attentional literacy.

Pupils should be guided to understand:

- that attention is a limited resource;
- that switching between tasks incurs a cognitive cost;
- that notifications can cause interference even when they are not opened;
- that the environment can be designed to facilitate concentration;
- that deliberate breaks are different from automatic interruptions;
- that digital wellbeing concerns the quality of the experience and not merely the duration of use.

From an educational perspective, short rituals to prepare the mind for focus, clearly defined periods of work on a single task, scheduled breaks and procedures for resuming work after an interruption can be introduced.

Rules regarding devices should be accompanied by a pedagogical explanation. A simple ban may temporarily restrict access, but does not guarantee the development of skills that can be transferred to non-school contexts. The aim should be to gradually enable pupils to manage tools, time and stimuli independently.

12. Limitations of the study

The first limitation concerns the relatively short duration of the intervention. Ten weeks may be sufficient to observe initial changes, but do not allow for the stability of new habits to be established.

The second limitation concerns the geographical location of the sample, which re-

duces the generalisability of the results. Subsequent studies should involve schools from different geographical areas and socio-economic backgrounds.
Some of the outcomes were assessed via self-report and may be influenced by social desirability. The integration with the d2-R, the comprehension test and usage data mitigates, but does not eliminate, this limitation.
The interruption diary requires self-monitoring skills and may underestimate the most automatic episodes. Device-based data, on the other hand, do not always allow for a distinction to be made between study-relevant and non-relevant use.
No medium-term follow-up was carried out. It would be advisable to conduct further assessments after three, six and twelve months to ascertain whether the strategies continue to be used after the programme has ended.
Randomisation by class reduces carry-over effects, but does not completely rule out differences related to teachers or the classroom atmosphere. These sources of variability must be accounted for in multilevel models.
Finally, the numerical and qualitative results presented in this draft are simulated. They illustrate the form the analysis might take, but cannot be used as empirical evidence prior to the study being carried out.

13. Conclusions

Attention fragmentation is one of the main educational challenges associated with the contemporary digital experience. The issue cannot be addressed solely by restricting device use or by placing the entire responsibility for control on students.

The simulated results suggest that a school programme based on the economics of attention, cognitive load, monotasking, metacognition and environmental design could improve concentration, reduce overload and strengthen self-regulation skills.
The key seems not to lie simply in reducing the time spent online, but in shifting from reactive and fragmented use to a more intentional, mindful approach that is consistent with learning objectives.

From this perspective, educating attention means providing students with the tools to recognise how their attention is directed, to protect it when necessary, to regain it after an interruption, and to use it in a way that is consistent with their own goals. Attention hygiene can therefore be considered an essential component of digital wellbeing and digital citizenship in the age of constant connectivity.

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