Enhancing Adolescent Attention through Specific Physical Education in the Digital Era

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ABSTRACT— This study explores how a personalized physical activity program can enhance adolescents' motor and cognitive functions. The program, based on the Sincrony methodology and embodied cognition theory, aims to counteract negative effects of excessive digital device use. Conducted in Italy with 64 girls aged 11–13, participants were randomly divided into three groups: a control group (general coordination exercises), a peripheral vision group (added peripheral vision stimuli), and a breathing group (focused on diaphragmatic breathing). Over 6 months, participants followed tailored training protocols. Results showed significant improvements in sustained attention ($p < .005$) and peripheral vision ($p < .001$), particularly in the peripheral vision group. The breathing group also exhibited moderate attention improvements. These findings suggest incorporating targeted physical education programs in schools to mitigate screen time effects and enhance cognitive and motor skills. Further research is needed to validate these results across diverse populations.

Over the past decades, the widespread diffusion of digital devices has led to substantial transformations in the ways young people interact with their surroundings. While these devices provide access to a broad range of educational resources, they have also raised significant concerns about their impact on the physical and cognitive development of users in adolescents. Research has established a relationship between excessive use of these technologies and adverse effects, including impairments in peripheral vision and reductions in executive function in children (Erickson, Gildengers, & Butters, 2013; Jandayan, Torreon, & Olandria, 2024; Murray et al., 2014; Presta, Guarnieri, Laurenti, & Mazzei, 2024). These effects are manifested in a decreased capacity to effectively process peripheral visual information fundamental for spatial orientation and in weakened executive and distributed attentional functions use for learning processes (Laurin, Ouerfelli-Ethier, Pisella, & Khan, 2019; Parkosadze, Tatishvili, Lomidze, & Kunchulia, 2019; Srikantharajah & Ellard, 2022). Simultaneously, physical activity has been widely recognized as important in mitigating these effects in many cultures and serves as a balancing tool against the negative consequences of excessive digital device use (Festa, Medori, & Macrì, 2023; Liang et al., 2023; Panjeti-Madan & Ranganathan, 2023). Additional scientific evidence has shown that physical education, rooted in movement, promotes well-being, cognitive function development, and brain plasticity in young people (Bidzan-Bluma & Lipowska, 2018; Zeng, Ayyub, Sun, & Wen, 2017; Zhang, Shi, Zhang, Li, & Feng, 2024). Physical activity has been indirectly linked to improvements in peripheral vision and executive control abilities, suggesting an existing interplay between physical and cognitive development. Specifically, the relevance of peripheral vision extends beyond the mere ability to perceive elements at the edge of the visual field. It enables the processing of visual information by activating distributed attention, allowing for the simultaneous and sustained intake of more information, albeit with fewer details (Naglieri &

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Das, 1990; Savage, Cornish, & Manly, 2006). These studies support the hypothesis that cognitive and physical development are intrinsically interlinked, with physical activity potentially acting as a catalyst for enhancing specific cognitive functions (Srinivas, Vimalan, Padmanabhan, & Gulyás, 2021). The paradigm of mind–body integration as an inseparable continuum has been advocated by numerous internationally recognized pedagogues and scholars. Early pioneering studies, such as those by Vygotskij (1978) and Piaget (1952), suggested that learning and intellectual development are deeply rooted in physical experience and bodily interaction. Similarly, Winnicott, a 20th-century British psychoanalyst and pediatrician, highlighted the importance of physical experience in psychological development, emphasizing the role of "holding" the physical and emotional containment provided by the mother, as the basis for mental development and the capacity to think. In a similar vein, Italian pedagogue Maria Montessori placed a strong emphasis on the interaction between mind and body in child learning, underscoring the utility of physical activity, particularly manual activities, in stimulating cognitive development. Another significant contribution from the past comes from Rousseau, whose treatise Emile (1762) promoted an education that integrates the body and senses for holistic development (Montessori, 1912; Piaget, 1952; Rousseau, 1762; Vygotskij, 1978; Winnicott, 1965). These reflections not only underscore the inseparability of movement and cognition but also pave the way for a broader understanding where the ability to think emerges from both this union and active engagement with the environment. The influential neuroscientific theory of embodied cognition posits that mind and body are united and interconnected with the environment (Shapiro, 2010, 2019). In this context, the importance of peripheral, primary sense linking humans to their surroundings, becomes particularly intriguing. As peripheral vision activates the processes of distributed attention that enable learning, it is essential to consider its role as a key integrative function connecting the body's perceptual capacities with the cognitive resources necessary for spatial orientation and learning, fully engaging all involved systems (Aoki & Cortese, 2018; Sporns, 2014). This function becomes especially critical during adolescence, a decisive developmental phase characterized by high brain plasticity and sensitivity to external stimuli (Jaswal, 2016; Narvaez & Tarsha, 2021; Perfeito, 2013). However, adolescence is also marked by increased use of digital tools, which predominantly stimulate central vision while reducing engagement with other perceptual systems. According to the World Health Organization (WHO), excessive digital device use is particularly prevalent among young people aged 11–17 (WHO, 2020). In this context, various researchers have investigated whether and how activities involving the body and environment might help reduce reliance on central vision. For instance, Schaper and Parés (2021) explored the potential of physical theater and found improvements in distributed attention correlated with increased spatial movement in young people. This highlights the potential importance of targeted training to stimulate peripheral vision as a means of balancing attentional focus (Voss, Kramer, & Basak, 2010). Additionally, Fogliata and Ambretti (2024) explored how peripheral vision could significantly enhance coordination between physical movement and visual perception, fostering more distributed attention and heightened spatial awareness. Similarly, Fehmi and Robbins (2008) demonstrated that specific peripheral vision training could improve the balance between distributed and focused attention. In Europe today, adolescents spend an average of 2–3 h per day on screens outside school hours a significant increase from the past, with negative implications for physical and cognitive health (Eurostat, 2018; HSE, 2023). A study by the Pew Research Center revealed that approximately 45% of adolescents report being online almost constantly, with substantial time spent on social media platforms such as YouTube, TikTok, and Snapchat (Pew Research Center, 2023). It is therefore critical to consider what forms of education might balance these negative effects. Structured physical education in mandatory school curricula that includes exercises targeting peripheral vision development could represent a viable solution. In this quest for solutions, an innovative movement education methodology called Sincrony (De Bernardi, 2008) offers practical exercise protocols designed to be integrated into physical education. The Sincrony methodology represents a novel approach compared to traditional methods by combining principles of biomechanics with techniques aimed at stimulating peripheral vision and distributed attention an aspect that has been underexplored in the literature on physical education for cognitive enhancement. The stimulation of peripheral vision within this methodology serves as a tool not only for improving motor skills but also for enhancing attentional capacities (Fogliata, Gamberini, & Ambretti, 2024; Wu, 2012). This study aims to observe whether integrating these protocols into adolescent school physical education can help mitigate the negative effects of excessive use of screen-focused digital tools (Kushwaha, Kushwaha, & Ahmad, 2024), specifically investigating the cognitive areas most documented as being influenced by this type of sensor-motor stimulation (Kadam & Shitre, 2019).

MATERIALS AND METHODS

The study involved 64 girls (mean age = 11.9; *SD* = ± 0.8) from the same school, randomly divided into three groups using a blind randomization process. Randomization was performed with software for random number generation. The operators conducting the assignments were unaware

Table 1
Coordination Training Protocol with Differentiated Focus

Group	*Focus*	*Main activities*
Control	General motor coordination*	- Warm-up (5 min): Light jogging, dynamic stretching (leg swings, arm circles). - Main exercises (30 min): Relay games (baton passing, cone navigation), Jump rope (single and double leg jumps, alternating speed), Agility courses (zigzag runs, ladder drills, step hurdles). - Cool-down (5 min): Static stretching (hamstrings, shoulders, calves).
Peripheral vision	Coordination with peripheral vision focus	*Same exercises as control group with additional emphasis on peripheral stimuli
Breathing	Coordination with diaphragmatic breathing focus	*Same exercises as control group with added focus on synchronized breathing during movements.

*In the experimental groups (Peripheral vision, Breathing), the same baseline coordination exercises as in the Control group were performed, with the specific additional focus indicated.

of the participants' identities. Blinding was applied to both participants and evaluators. The sample size was determined considering the logistical constraints of the school, and a retrospective power analysis was conducted. This analysis indicated that with 64 participants divided into three groups, a statistical power above 80% could be achieved ($\alpha = 0.05$).

Group 1 (Control): $N = 21$, mean age = 11.8, $SD = 0.7$. This group performed general coordination exercises.

Group 2 (Peripheral Vision Sincrony): $N = 22$, mean age = 12, $SD = 0.6$. This Group performed the same general coordination exercises as the control Group, supplemented with peripheral vision stimuli and corrections to attentional focus (Sincrony methodology).

Group 3 (Breathing Sincrony): $N = 21$, mean age = 11.9, $SD = 0.9$. This Group performed the same general coordination exercises as the control Group, supplemented with diaphragmatic breathing exercises and a focus on breathing. Each Group participated in a six-month training program consisting of two 40-min sessions per week. All activities were conducted in a blind manner, following the Sincrony methodology to stimulate specific motor skills (as in Table 1). The progression of exercises was structured to gradually increase in difficulty, aligning with the objectives of each Group. In the first 2 months, the exercises focused on learning and mastering basic movements. Subsequently, exercises with shorter execution times and greater complexity were introduced. During the fifth and sixth months, the difficulty was further increased by incorporating competitive elements and higher physical intensity.

The selection criteria for participants were: aged between 11 and 13 years (Best, 2012a; Best, 2012b; WHO, 2022); female gender, considering gender differences in cognitive processing and physical stimuli responses (Tiggemann & Slater, 2013). Furthermore, this selection allowed for greater statistical control by limiting interindividual variability in maturational and sensorimotor profiles, which tend to diverge between sexes during early adolescence. In the context of a pilot study with a moderate sample size, gender homogeneity supports more robust intragroup comparisons and enhances the precision of effect estimation across the intervention arms. Participants also reported engaging weekly in moderate physical activity levels, assessed using the Physical Activity Questionnaire for Children (PAQ-C) (Kowalski, Crocker, & Donen, 2004; Rowlands, 2007); and daily use of digital devices ranging from 90 to 120 min, measured via the Questionnaire on Teenage Media Use (Rideout, Foehr, & Roberts, 2010), consistent with European data (Knowledge for Policy, 2021). Participants who failed to complete at least 90% of the program or had physical/medical limitations were excluded. All subjects maintained their regular exercise routines and screen usage habits during the experimental semester. Additionally, a familiarization period with the testing protocols was conducted 3 weeks prior to the experiment's start to ensure procedural understanding and minimize novelty-related bias. All participants were tested at two different time points: T1 (before the experiment began) and T2 (after its conclusion). A battery of tests and tools was used to evaluate specific aspects of the participants' cognitive, physical, and visual functions:

GO/NO GO Test: Used to analyze executive functions, particularly cognitive control and behavioral inhibition. Participants were presented with stimuli to which they had to respond ("GO") or inhibit their response ("NO GO") in the gym, with timing set by a metronome (Kim, Iwaki, Imashioya, Uno, & Fujita, 2007; Peters, Waber, McAnulty, & Duffy, 2003; Simmonds, Pekar, & Mostofsky, 2008).

Digit Span Test: Designed to assess verbal working memory and attention. Participants were presented with numerical sequences to repeat in their original order; evaluating short-term memory (Conway et al., 2005; Engle, Tuholski, Laughlin, & Conway, 1999).

Visual Field Confrontation Test: Used to assess peripheral vision. The examiner, positioned in front of the participants, asked them to locate specific objects distributed across the participant's peripheral visual field using marked visual indicators, and the participants were required to report stimulus detection. Errors and omissions were recorded (Johnson, 1996).

Modified Cooper Test (8-min duration): Adapted for adolescents, this test, introduced by Cooper (1968), provides an estimate of maximum oxygen uptake (VO2 max) and is a key reference for assessing physical performance (Aerobic Capacity).

Anthropometric Measurements: Weight, height, and body mass index (BMI) were measured to monitor growth and development (Heyward & Stolarczyk, 1996). Resting and exercise heart rates (BPM) were recorded as indicators of cardiovascular condition and physiological response to exercise (Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012). Respiratory rate was assessed following the guidelines of the American Thoracic Society (1995) to estimate respiratory capacity.

Data Analysis

The data were analyzed using SPSS software (IBM 20). Descriptive statistical analyses were conducted to compare test performance between T1 (initial phase) and T2 (end of the semester) across the different Groups (as in Table 2).

Correlations between screen-based digital device usage (Questionnaire Scores) and initial test results were explored using Pearson's correlation coefficient:

Attentive Capacity (DIGIT): The correlation between hours spent on devices and DIGIT scores showed a coefficient of 0.236 ($p = .058$). While not significant, the result was trending toward significance.

Peripheral Vision (VFCT): A significant positive correlation was found between hours spent on devices and VFCT scores ($r = 0.363$, $p = .003$), indicating a significant association at the 1% level.

Executive Functions (GO/NOGO): The correlation between hours spent on devices and GO/NOGO test scores was not significant ($r = 0.155$, $p = .216$).

Aerobic Capacity (Cooper): The correlation between hours spent on devices and Cooper test scores was not significant ($r = -0.193$, $p = .123$).

Correlations between Anthropometric Parameters and Performance

Relationships between anthropometric parameters (BMI, weight, height) and cognitive and motor test scores were also explored using Pearson's correlation coefficient. Key findings include:

VFCT (Peripheral Vision):

No significant correlation was observed between BMI and VFCT T2 performance ($r = -0.12$, $p = .45$).

Nonsignificant correlations were also found for weight and height ($p > .20$ for both).

DIGIT (Attentive Capacity):

No significant correlation was found between BMI and DIGIT T2 scores ($r = 0.08$, $p = .56$).

Weight and height showed no significant associations with attentive capacity ($p > .30$).

GO/NOGO (Executive Functions):

For the GO/NOGO test, no significant relationship emerged between BMI and performance ($r = 0.05$, $p = .70$).

Correlations with weight and height were also nonsignificant ($p > .40$).

Cooper:

While not significant, weak correlations were found between BMI and distance covered ($r = -0.15$, $p = .28$), suggesting a possible trend warranting further investigation.

No significant correlations were observed for weight and height ($p > .30$).

Inferential Analysis

The normality of data was tested using the Shapiro–Wilk test. Results confirmed that data related to peripheral vision scores (VFCT), attentive capacity (DIGIT), executive functions (GO/NOGO), and aerobic capacity (Cooper) followed a normal distribution ($p > .05$ for all Groups). Homogeneity of variances was also tested using Levene's test, which showed acceptable homogeneity across groups ($p > .05$). A one-way standard analysis of variance (ANOVA) was conducted to compare differences between groups in the various

Table 2
Descriptive Statistics by Group and Time Point

Test	*Group 1 T1*	*Group 1 T2*	*Group 2 T1*	*Group 2 T2*	*Group 3 T1*	*Group 3 T2*
DIGIT	4.2 ± 0.5	4.3 ± 0.4	4.1 ± 0.6	4.8 ± 0.3	4.0 ± 0.4	4.9 ± 0.2
VFCT	12.0 ± 2.1	12.2 ± 2.0	11.8 ± 2.0	10.9 ± 1.4	12.1 ± 2.2	11.8 ± 1.8
GO/NO GO	10.3 ± 1.4	10.4 ± 1.3	10.4 ± 1.5	10.9 ± 1.3	10.5 ± 1.6	10.6 ± 1.4
COOPER	1100 ± 180	1120 ± 170	1090 ± 160	1110 ± 170	1105 ± 175	1115 ± 165

tests at both the initial time (T1) and final time (T2) (as in Table 3).

Post hoc Tukey honestly significant difference (HSD) tests were applied to further investigate significant group differences identified by ANOVA. Only the tests showing significant differences in ANOVA were included in the post hoc analysis (as in Table 4).

DISCUSSION

The study results highlighted significant improvements in selected variables within the intervention groups (2 and 3) compared to the control group (1). These findings support the hypothesis that targeted physical education activities have a more substantial impact on specific cognitive and motor abilities than general programs. Moreover, the absence of significant changes in the control group confirms that the observed improvements in the experimental groups can be attributed to the structured interventions. Anthropometric analyses revealed no significant correlations between weight, height, or BMI and performance in cognitive or motor tests. This suggests that the observed improvements were independent of participants' physical condition. In the Peripheral Vision Test (VFCT), Group 2, which underwent peripheral vision training, showed significantly greater improvements than both Group 1 ($p < .001$) and Group 3 ($p = .02$), with a mean reduction in errors of 0.9 ± 0.1. This aligns with previous literature indicating that peripheral visual stimulation enhances visual processing and visuomotor coordination (Bavelier, Green, Pouget, & Schrater, 2012). In parallel, the same group also showed improved attention test scores ($p = .019$), suggesting that integrating peripheral stimuli may have a positive indirect effect on cognitive functions. Group 3 demonstrated significant gains in attention as well ($p = .001$), likely due to the combined effects of enhanced concentration and stress regulation induced by diaphragmatic breathing. This interpretation is supported by evidence from mindfulness literature that links breathing control with improved cognitive performance (Ahmad, Hussain, Mustaqeem, & Kushwaha, 2024). The decision to focus on female participants was driven by the need to reduce developmental variability in an already limited sample size. In early adolescence, girls typically show more stable attentional and sensorimotor development trajectories, which supports more consistent group comparisons. Furthermore, recruitment was facilitated by the structure of the participating school, where male students were fewer and unevenly distributed across classes. Gender homogeneity thus allowed for stronger internal validity and more reliable effect estimation in this pilot context. Nonetheless, future research should aim to include both genders and a broader demographic to assess the intervention's applicability across more diverse populations and educational settings. Regarding executive function, no significant between-group differences were found in the GO/NO GO task at T2 ($p = .679$). However, Group 2 displayed a trend toward significance ($p = .059$), which may suggest a weak emerging effect. Although the peripheral vision training was not specifically designed to enhance inhibitory control, it may have indirectly activated attentional and sensorimotor circuits involved in cognitive flexibility. It is plausible that extended or more intensive exposure to such stimuli could yield stronger effects in tasks requiring sustained inhibition. Future studies could explore this using more sensitive executive function measures or complementary neuroimaging techniques. The absence of significant improvements in both executive functions and aerobic capacity likely reflects a combination of methodological and design-related factors. The lack of significant improvements in executive function and aerobic capacity can be attributed to a combination of intervention design and measurement limitations. The activities were not tailored to specifically enhance cardiovascular fitness or high-level executive processes. Moreover, the training intensity, two 40-min sessions per week, may have

Table 3
Analysis of Variance (ANOVA) Results

TEST	*T1*	*T2*
DIGIT	$p = .001$*	$p < .001$*
VFCT	$p = .594$	$p < .001$*
GO/NO GO	$p = .059$	$p = .679$
COOPER	$p = .205$	$p = .818$

*Significativity.

Table 4
Post Hoc Results

Test	*Comparison*	*Mean difference*	*p-value*
VFCT	Peripheral vision versus control	−0.9 ± 0.1	<.001*
Peripheral vision versus breathing	−0.6 ± 0.2	0.02	>.05
DIGIT attention	Peripheral vision versus control	+5.2 ± 1.3	.005*
Peripheral vision versus breathing	+3.7 ± 1.1	0.03	>.05

*$p < .05$ indicates statistically significant difference.

been inadequate to trigger measurable adaptations, especially in already moderately active adolescents. While the measurement tools were validated, their sensitivity might have been insufficient to detect subtle short-term changes. These factors collectively highlight the need for more intensive protocols and more precise assessments in future studies. In the case of the GO/NO GO task, the trend toward significance in Group 2 may also reflect a potential Type II error due to limited sample size. Although the study was appropriately powered for a school-based pilot, it may not have been sufficient to detect small but meaningful effects. This highlights the need for future research with larger samples, more intensive training protocols, and more sensitive outcome measures, including digital assessments or neuropsychological batteries. Booster sessions or increased training frequency could further enhance the effectiveness of the intervention on both aerobic and cognitive outcomes. In conclusion, the findings underscore the potential value of integrating targeted motor and cognitive stimuli, such as peripheral vision training and diaphragmatic breathing, into physical education programs to enhance attentional and visuomotor performance. To strengthen the external validity of these results, future research should include mixed-gender samples and a wider variety of socioeconomic and cultural backgrounds, allowing for a more comprehensive evaluation of the intervention's generalizability and long-term effects.

CONCLUSIONS

This study highlighted how a targeted physical activity program focusing on peripheral vision stimulation exercises can positively impact adolescents' attentional and visual abilities. The results show significant improvements in attention capacity and peripheral vision (Ambretti, Fogliata, & Di Palma, 2024), suggesting that specific exercises may help mitigate the negative effects of intensive digital device use, often associated with reduced distributed attention and limited visual focus. Additionally, the Group engaged in diaphragmatic breathing exercises demonstrated improvements, albeit less pronounced, in attention capacity, aligning with existing literature on the role of breathing in stress reduction and enhanced concentration (Ma, Yue, Gong, Zhang, & Duan, 2017). These findings open new perspectives for revising school physical education programs, advocating for the integration of exercises that support cognitive abilities, which are increasingly challenged by modern lifestyles. Schools could benefit from updating curricula to adopt multidisciplinary approaches that address adolescents' emerging needs. It is important to note that the study sample, while meaningful, was limited to a specific age range and gender, and the intervention duration was relatively short, potentially not reflecting the long-term effects of such activities. Further research involving larger and more diverse samples is necessary to confirm and expand upon these findings. In conclusion, given the current context, innovative and targeted educational strategies may prove valuable in balancing the cognitive challenges posed by the lifestyles of today's adolescents. To strengthen the external validity of these findings, future research should involve mixed samples and extend the implementation to different populations and cultural contexts, allowing for a broader evaluation of the applicability of the intervention in diverse educational contexts.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

ETHICS APPROVAL

In accordance with Law 219/2017 on informed consent and the General Data Protection Regulation (GDPR, EU Regulation 2016/679), formal ethical approval was not required as the study did not involve invasive procedures or medical treatments. However, written informed consent was obtained from all participants and their legal guardians. Additionally, official authorization from the school administration was requested and granted to conduct the study within the institution, ensuring full compliance with current regulations on data protection and participant rights. Authorization granted by the school administration under protocol no. 2023/04567. The approval was obtained in accordance with school institutional guidelines and national regulations. Any supplementary data may be made available upon reasonable request, in compliance with data protection regulations and with prior authorization from the relevant authorities. The study adhered to the Declaration of Helsinki and was approved. Consent was provided by participants' parents or caregivers.

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DATA AVAILABILITY STATEMENT

The data collected in this study cannot be publicly shared due to current privacy regulations in Italian educational institutions (General Data Protection Regulation – GDPR, EU Regulation 2016/679). However, all participants and their legal guardians provided written informed consent prior to participation. Participants' anonymity was fully maintained, and all data were processed in aggregated form to ensure confidentiality.

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