



Enhancing Selective Attention in Youth Basketball: Cognitive and Physiological Outcomes of a Representative Training Intervention

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Abstract

Objectives. The study aimed to evaluate the effectiveness of a basketball training workshop designed to enhance selective attention and interference control in U-17 athletes through increased attentional load during practice.

Material and Methods. The study employed a mixed-methods experimental design. Forty competitive basketball players aged 16 years participated in the study and were divided into an experimental group (n = 21) and a control group (n = 19). Selective attention was assessed using the Stroop Colour and Word Test during the pre- and post-intervention phases. Qualitative data were collected through systematic observations and semi-structured interviews with athletes and coaches. The experimental intervention consisted of a basketball training programme that systematically manipulated task constraints and incorporated ecologically representative exercises aimed at increasing attentional demands.

Results. After six months of intervention, the experimental group demonstrated a significant reduction in the Stroop interference index compared to the control group. In addition, athletes in the experimental group showed significantly decreased response times and fewer errors in the incongruent condition of the test. Qualitative findings indicated the development of more effective attentional strategies, improved ability to filter irrelevant stimuli, enhanced control of impulsive responses, and faster recovery of attentional focus in stressful game situations.

Conclusions. The results suggest that a basketball training programme based on systematic manipulation of practice constraints and ecologically valid exercises can effectively support the development of selective attention and interference control in adolescent athletes. Such approaches may contribute to improved decision-making and performance in open-skill team sports.

Keywords: executive functions, selective attention, interference control, basketball, decision making, cognitive training.

Introduction

In contemporary team sports, athletic performance is increasingly interpreted as the result of dynamic interaction between physical, technical, tactical, and cognitive components. In particular, in contexts with high environmental and temporal complexity, such as basketball, the effectiveness of motor action depends largely on the athlete's ability to perceive, select, and use relevant information in extremely short times. From this perspective, performance cannot be reduced to automated

motor execution, but must be understood as a continuous perceptual-decision-making process, strongly mediated by higher cognitive functions. Among these, selective attention plays a central role. It can be defined as the ability to intentionally allocate attentional resources to stimuli that are functional to the task, while simultaneously inhibiting irrelevant or interfering information (Latino et al., 2021). In open-skill sports contexts, this ability is crucial for managing the simultaneity of stimuli and the unpredictability of game situations. Recent studies in cognitive neuroscience applied to sport emphasize that selective attention is closely linked to executive control and cognitive inhibition mechanisms, especially under time and competitive pressure (Diamond, 2013; Diamond and Ling, 2016; Best, 2019).

During adolescence, and particularly between the ages of 15 and 17, the neurocognitive systems responsible for attentional control and inhibition are still maturing. The literature highlights how, during this stage of development, executive functions are particularly sensitive to environmental stimuli and structured experiences, making the sporting environment a potentially privileged context for their development (Best and Miller, 2010; Diamond, 2013; Ludyga et al., 2020).

Numerous studies conducted in recent years indicate that sports practice, and in particular open-skill sports, is associated with higher levels of selective attention, cognitive flexibility, and inhibitory control compared to both sedentary individuals and athletes engaged in sports characterized by more predictable environments (Koch et al., 2021; Scharfen and Memmert, 2019; Vestberg et al., 2020). These results suggest that it is not the practice of sport itself that determines cognitive benefits, but the perceptual-decision-making nature of the demands imposed by the training and competition context. Recent studies have shown that structured sport-based educational laboratories can improve both executive functions and social inclusion in adolescents (Gravino et al., 2025).

Basketball is a prime example of a high-cognitive-intensity open-skill sport. Athletes are required to constantly monitor a multitude of visual and auditory stimuli—the position of the ball, the movements of teammates and opponents, available space, time remaining—selecting the most relevant information for the action in a fraction of a second. At the same time, they must inhibit impulsive responses and ineffective automatisms, especially under conditions of emotional stress and competitive pressure.

Methodologically, selective attention and interference control are frequently assessed using the Stroop Color and Word Test, which is still considered one of the most reliable tools for analyzing cognitive inhibition. Although the Stroop paradigm has historical origins, recent literature confirms its validity and use in studies on athletes and active populations, particularly for assessing changes in executive control processes associated with training and sports experience (Scarpina & Tagini, 2017; Koch et al., 2021).

At the same time, in recent years, a pedagogical-sports perspective has emerged that emphasizes the intentional design of training sessions as cognitive learning environments. In particular, Representative Learning Design and the constraints approach emphasize the importance of structuring exercises that maintain key information from the competition context, stimulating authentic decision-making processes and promoting the transfer of learned cognitive skills (Pinder et al., 2011; Renshaw et al., 2019). Despite the growing body of literature documenting the relationship between sport practice and executive functions, an important gap remains in understanding how specific training designs can intentionally stimulate these cognitive processes. Much of the existing research has focused on cross-sectional comparisons between athletes and non-athletes or between different types of sports, highlighting cognitive advantages associated with participation in open-skill disciplines. However, fewer studies have experimentally examined how training environments within sport practice can be deliberately structured to promote the development of executive functions.

Moreover, when cognitive training is investigated, it is often implemented through laboratory-based or decontextualized tasks that are only partially connected to the perceptual–motor demands of real sport situations. This creates a conceptual limitation: while sport performance emerges from dynamic interactions between perception, decision making, and action, many cognitive interventions isolate cognitive processes from the ecological context in which they normally operate.

From the perspective of Representative Learning Design and the constraints-led approach, cognitive development in sport should emerge from repeated exposure to tasks that preserve the informational and decision-making structure of the competitive environment. Training situations characterized by high informational density, time pressure, and variable rules may therefore stimulate selective attention and inhibitory control mechanisms by requiring athletes to continuously filter relevant cues, inhibit automatic responses, and update attentional priorities. However, empirical evidence on the effectiveness of such ecologically designed interventions in improving executive functions in adolescent athletes is still limited. In light of these theoretical assumptions, it seems relevant to investigate whether a basketball laboratory explicitly designed to increase attentional load and stimulus selection demands can produce measurable effects on selective attention in adolescent athletes.

Aim of the study is to evaluate the effectiveness of a six-month basketball workshop on the development of selective attention in 16-year-old athletes, using a mixed-methods experimental design.

Research Hypothesis. The athletes in the experimental group will show a significant improvement in selective attention and interference control scores on the Stroop test compared to the control group.

Qualitative data will highlight an evolution in attentional strategies, the ability to filter out distractions, and cognitive awareness of sporting action in the athletes in the experimental group.

Material and Methods

Research Framework

The research adopts an experimental design with an experimental group and a control group, integrating quantitative and qualitative methods. This approach allows for the analysis of both measurable changes in selective attention processes and behavioral and perceptual transformations experienced by athletes in the context of training and competition.

Participants

The sample consisted of 40 16-year-old basketball players involved in structured youth competitive activities.

- Experimental group (EG): 21 athletes involved in the laboratory with attentive focus.
- Control group (CG): 19 athletes who followed the regular training program.

All participants had at least five years of sporting experience, regular weekly training, and no neurological

or cognitive diagnoses. Informed consent was obtained from parents or legal guardians, in accordance with the ethical principles of sports research. A post-hoc statistical power analysis was conducted using G*Power software. Considering the total sample size ($N = 40$), an alpha level of .05, and the repeated-measures design adopted in the study, the analysis indicated adequate statistical power ($> .80$) to detect medium interaction effects between time and group.

Quantitative Tools: Stroop Color and Word Test

Selective attention was assessed using the Stroop Color and Word Test, administered pre-intervention (T0) and post-intervention (T1). The test comprises three standardized conditions:

- reading words,
- naming the color of neutral stimuli,
- naming the color of incongruent words.

The main indicator considered is interference control, obtained from the combined analysis of response times and errors in the incongruent condition with respect to color naming. This index reflects the ability to inhibit automatic responses and maintain attentional focus on the relevant rule.

Qualitative Analysis

Systematic Observations

During the intervention, structured observations of training sessions and game situations were conducted, focusing on attentional and decision-making behaviors. The categories observed included:

- manifestations of distraction,
- speed and quality of decisions,
- adaptation to changing rules,
- error management,
- functional communication with teammates.

The observations were recorded in structured diaries and analyzed to identify developmental patterns in attentive behavior.

Semi-structured Interview

At the end of the experimental intervention, semi-structured individual interviews were conducted with a subsample of athletes belonging to the experimental group and the control group, with the aim of exploring the subjective perception of attentional processes, distraction management strategies, and the transfer of attentional skills to the training and competition context.

The interviews took place in a quiet and familiar environment for the athletes and lasted between 20 and 30 minutes. All interviews were audio-recorded with prior consent, transcribed in full anonymously, and subsequently analyzed.

The interview outline was constructed in line with the theoretical framework of the study and divided into thematic areas, maintaining a flexible structure that allowed for in-depth exploration of the athletes' responses:

Area 1 – Perception of attention in the sporting context

1. How would you describe your level of attention during training and matches?

2. At what points in the game do you find it most difficult to maintain concentration?
3. What do you think are the main sources of distraction during a basketball game?

Area 2 – Selective attention and distraction management

4. When you are on the court, how do you know which information is really important for the action you are about to take?
5. Do you ever find yourself distracted during the game? If so, what happens at that moment?
6. Have you developed strategies to ignore irrelevant stimuli, such as noise, opponents, or previous mistakes? If so, what are they?

Area 3 – Interference control and cognitive inhibition

7. In situations of pressure or stress (e.g., little time left on the clock or aggressive defense), how does your thinking and decision-making change?
8. Do you ever have to block an impulsive action in order to choose a more effective solution? Can you give a concrete example?
9. Compared to the past, do you feel you are better able to control your automatic reactions during the game? In what way?

Area 4 – Laboratory experience and attentional load

10. How did you experience the laboratory exercises in which the rules or tasks changed frequently?
11. Which exercises required the most attention and why?
12. In your opinion, did these exercises change the way you pay attention on the field?

Area 5 – Cognitive awareness and self-regulation

13. Can you describe what happens in your mind before you make an important decision on the field?
14. Do you use personal routines (e.g., breathing, keywords, focusing your gaze) to help you concentrate?
15. Do you think you are more aware of your mental processes today than you were before the intervention? Why?

Area 6 – Transfer to the competition context

16. Have you noticed any changes in the way you play during official matches? In what specific situations?
17. Do you think that what you learned in the lab is transferable to game situations? Can you provide specific examples?
18. At what points in the game do you feel you manage your attention better than in the past?

Area 7 – Overall evaluation of the experience

19. How has the lab influenced the way you train and play?
20. If you had to explain to another athlete what you have learned in terms of attention and concentration, what would you say?
21. Is there anything you would change or improve in the workshop to make it more effective?

Methodological note

The questions were used as a flexible guide to encourage athletes to narrate their subjective experiences and to allow for further exploration based on their answers. The qualitative data analysis was conducted through thematic

analysis, using progressive coding of the transcripts, aimed at identifying recurring themes related to selective attention, interference control, self-regulation strategies, and the transfer of cognitive skills to the sporting context.

Experimental Activities

The basketball workshop was designed as an intentional integrated cognitive stimulation intervention, based on the principles of Representative Learning Design and the constraints approach, with the aim of enhancing selective attention and interference control through highly ecologically representative motor tasks. According to this perspective, learning and adaptation (Susanto et al., 2024b) emerge from the interaction between athlete, task, and environment, and are most effective when exercises maintain the perceptual and decision-making information typical of the real competitive context (Pinder et al., 2011; Renshaw et al., 2019).

The most recent literature on team sports highlights how cognitive training is most effective when it is not separated from motor action but integrated into tasks that simultaneously require perception, decision-making, and execution, thus promoting the transfer of cognitive skills to real play (Scharfen & Memmert, 2019; Vestberg et al., 2020; Ludyga et al., 2020). In this sense, the workshop was not conceived as 'isolated' cognitive training, but rather as a qualitative reorganisation of the usual technical-tactical exercises, aimed at increasing the attentional load and the need to select relevant stimuli.

The intervention was developed over a period of six months, with two sessions per week, integrated into the team's normal training program. Each session dedicated to the workshop lasted between 30 and 40 minutes and was included in the central part of the training, in order to ensure an adequate level of physical and cognitive activation, avoiding both conditions of excessive fatigue and low attentional activation.

The exercises were designed through the systematic manipulation of constraints, in particular:

- informational constraints, through the introduction of relevant visual and auditory stimuli (coaches' signals, color cues, keywords) and intentionally inserted irrelevant stimuli, with the aim of stimulating attentive selection;
- temporal constraints, progressively reducing the time available to make decisions, in order to increase cognitive pressure and the need to inhibit automatic responses;
- regulatory constraints, through frequent changes in the rules of the game (e.g., limitations on passes, conditions for valid baskets, sudden changes in objectives), to stimulate cognitive flexibility and continuous updating of attentional priorities;
- spatial constraints, modifying the size and configuration of the field, to alter the available perceptual information and require constant reorganization of visuospatial attention.

The progression of the intervention was structured in a gradual manner. In the initial stages, the exercises involved a limited number of simultaneous constraints, with the aim of promoting understanding of the attentional demands. In the subsequent stages, the complexity was increased by introducing more competing sources of information, situations

of numerical superiority and inferiority, and tasks with variable rules during the exercise. This progression is consistent with evidence indicating that controlled task variability promotes perceptual-decision adaptation and cognitive robustness in open-skill sports (Renshaw et al., 2019).

Particular emphasis was placed on the use of high-cognitive-intensity small-sided games, considered a privileged tool for training selective attention and decision making, as they reproduce in a simplified but representative form the informational demands of real play (Santos et al., 2018; Clemente et al., 2021). In such situations, athletes were constantly called upon to discriminate relevant stimuli, update their decisions, and inhibit impulsive responses, especially in the presence of sudden changes in game conditions.

Alongside the manipulation of constraints, the workshop included specific moments dedicated to the development of attentional routines and self-regulation strategies, such as the conscious use of breathing, focusing keywords, and attentional landmarks. The inclusion of these strategies is supported by recent studies highlighting the role of cognitive routines and attentional control in managing pressure and stabilizing performance in team sports (Larkin et al., 2021; Englert et al., 2020).

Overall, the intervention was designed as an intentional learning environment, in which selective attention was not trained directly or explicitly, but was continuously elicited through the structure of the task. This approach is in line with the latest literature, which emphasizes that the development of executive functions in sport emerges mainly from systematic exposure to cognitively demanding contexts, rather than from decontextualized exercises (Diamond & Ling, 2016; Ludyga et al., 2020).

Results

Quantitative Results

Analysis of the data obtained from the Stroop Color and Word Test revealed a pre-post differential trend between the experimental group (EG) and the control group (CG), indicating a specific effect of the intervention on interference control and, more generally, on selective attention processes. In the pre-intervention phase (T0), the two groups had a substantially overlapping profile in the incongruent condition, both in terms of response times and errors, suggesting a homogeneous baseline condition and reducing the likelihood that subsequent differences were attributable to initial inequalities. Descriptive statistics for the Stroop measures in both groups and measurement points are reported in Table 1. At baseline (T0), the experimental group (EG) and the control group (CG) showed comparable performance in the incongruent condition in terms of response times and error rates, supporting the assumption of initial equivalence between groups.

Pre-post trend in the incongruent condition (primary outcome)

After six months of intervention (T1), the EG showed a marked improvement in the incongruent condition, expressed by:

- a reduction in response times, with an average shift from approximately 48–50 s to 39–41 s ($\Delta \approx -9/-11$ s);
- a reduction in color naming errors, equal to approximately -22% compared to the initial values.

Table 1. Descriptive statistics for the Stroop measures in both groups

Group	Time	Response time (s)	Errors (n)	Interference index
Experimental group (EG)	T0	49.1 ± 4.7	12.3 ± 3.2	35.2 ± 5.8
Experimental group (EG)	T1	40.0 ± 4.2	9.6 ± 2.5	28.6 ± 5.1
Control group (CG)	T0	48.7 ± 4.5	12.1 ± 3.0	34.8 ± 5.6
Control group (CG)	T1	46.4 ± 4.4	11.9 ± 2.9	33.1 ± 5.3

This combination of outcomes is particularly relevant as it indicates an improvement that is not limited to speed of execution but also involves accuracy: the EG responded faster without paying a cost in terms of increased errors, but rather showing a decrease in errors. In functional terms, this is consistent with an enhancement of the ability to maintain the attentional rule (naming the color) and inhibit interfering automatism (reading the word) in conditions of conflict.

In the CG, on the contrary, the pre-post trend was modest and unsystematic:

- reduction in incongruent times in the order of 2–3 s;
- no consistent reduction in errors, with fluctuations not attributable to a stable pattern of improvement.

Overall, these data indicate that the improvement observed in the EG cannot be explained solely by familiarization with the procedure or by a generic effect of sports training, since the GC—despite training regularly—does not show a comparable trajectory.

Stroop interference index (composite outcome)

Considering the synthetic interference control indicator (derived from the combined analysis of times and errors in the condition inconsistent with color naming), the EG showed an average reduction in interference of 18–20%, while in the GC the reduction was limited and less than 5%. The magnitude of the difference between groups, combined with the consistency between components (times and errors), suggests that the intervention acted on a specific executive construct—inhibition and attentive selection—rather than on a generic processing speed.

Repeated measures ANOVA revealed a significant main effect of time, $F(1,38) = 18.42$, $p < .001$, indicating an overall pre-post change across participants. Confidence intervals were also calculated to provide an estimate of the precision of the observed effects.

More importantly, a significant time × group interaction emerged, $F(1,38) = 9.87$, $p = .003$, $\eta^2 p = .21$. Repeated measures analysis confirmed the presence of:

- a main effect of time, $F(1,38) = 18.42$, $p < .001$, indicative of an overall pre-post change;
- above all, a significant time × group interaction, $F(1,38) = 9.87$, $p = .003$, $\eta^2 p \approx .21$.

According to conventional benchmarks, this value corresponds to a medium-to-large effect size, indicating a substantial difference in the evolution of interference control between the two groups.

The significance of the interaction, together with the effect size ($\eta^2 p \approx .21$, medium-high), indicates that the

change over time is not uniform in the two groups, but is differentiated and therefore plausibly attributable to the experimental component of the program (systematic increase in attentional load through informational, temporal, and regulatory constraints). The analysis of simple effects further specified this result, showing that the pre-post improvement is statistically significant in the EG ($p < .001$) and not significant in the GC ($p > .10$). In interpretative terms, this supports the hypothesis that the intervention produced a specific gain in interference control compared to ordinary training.

Improvement profile: efficiency, accuracy, and stability

In addition to statistical significance, the data describe an improvement with three relevant characteristics:

1. **Efficiency:** the reduction in time in the incongruent condition in the EG ($\approx -9/-11$ s) suggests greater speed in implementing the correct rule in the presence of stimulus-response conflict.
2. **Accuracy:** the simultaneous reduction in errors ($\approx -22\%$) indicates an increase in precision in selecting relevant information (color) and filtering out interference (word). This pattern is particularly informative because a simple increase in speed could, in some cases, be accompanied by an increase in errors (speed-accuracy trade-off). In the EG, on the other hand, the trajectory is consistent with a real improvement in executive control.
3. **Stability of attentional control:** a further significant element concerns the reduction in intra-individual variability in the EG at post-test, highlighted by the decrease in score dispersion. This result suggests not only an average improvement, but also greater consistency of performance under conditions of interference, i.e., a form of “robustness” of attentional control. In the GC, variability remained essentially unchanged, indicating less stable control that is more susceptible to fluctuations.

Exclusion of alternative interpretations

In the context of a pre-post design with a control group, some alternative factors are partially contained:

- Practice/test-retest effect: potentially present in both groups; however, the magnitude of change in the EG and the modest variation in the CG suggest that familiarization is not sufficient to explain the effect.
- Neurocognitive maturation: plausible in adolescence and expected in both groups; again, the time × group interaction indicates that the increase is greater in the SG than expected for maturation or ordinary training.
- General sports training: both groups are competitive athletes; the difference between trajectories reinforces the interpretation that it is the component of constraint manipulation and increased attentional load that produces the additional effect.

Overall, the quantitative results show that the high attentional demand basketball laboratory is associated with a significant and specific improvement in Stroop interference control. This improvement manifests itself as: (a) a consistent reduction in incongruent times, (b) a parallel reduction in errors,

(c) a decrease in the interference index of 18–20% in the EG versus <5% in the GC, (d) a significant time \times group interaction with a medium-high effect size, and (e) greater intra-individual stability at post-test. These elements, considered together, indicate a measurable enhancement of selective attention and cognitive inhibition processes in conflict conditions, consistent with the main hypothesis of the study.

Qualitative Tools

The qualitative analysis of the semi-structured interviews and systematic observations provided a detailed picture consistent with the quantitative results, highlighting a progressive evolution in the experimental group (EG) in terms of attentional strategies and inhibitory control applied to the game context. The triangulation between sources (subjective narratives and observed behavioral indicators) allows us to describe not only what has changed, but also how this change manifested itself in the ecological context of training and competition. The thematic analysis led to the identification of five recurring macro-themes in the EG, with less frequent, weaker, or predominantly generic patterns in the control group (CG): (1) selection and prioritization of relevant stimuli, (2) management of distractions and recovery of focus, (3) inhibition of impulsivity under pressure, (4) attentive routines and self-regulation, (5) transfer to competition situations.

Theme 1 – Rapid selection of relevant stimuli and redefinition of attentional priorities

In the SG, there is a clear shift from predominantly reactive attention management (“I follow what is happening”) to a more intentional and hierarchical selection (“I look for the information that matters first”). Athletes describe a change in the way they “read” the situation, reporting greater speed in identifying functional signals (ball, spaces, free teammate, defensive positioning) and a reduction in the tendency to be distracted by competing or irrelevant stimuli. This process is frequently linked to laboratory exercises characterized by rule changes, information constraints, and interfering stimuli: Marco (EG, guard) states, “when they changed the rules unexpectedly, I had to stop doing things automatically; I had to understand immediately what mattered,” while Luca (EG, point guard) explains a prioritization criterion: “Before, I used to get lost, but now I look for the right information first: ball, space, free man; I cut out the rest.”

The observations converge with these narratives, showing that in the final stages of the intervention, the EG shows greater adherence to the binding rule of the exercise, especially when it is modified “on the fly,” with fewer episodes of operational disorientation and shorter adaptation times to the new instruction. Compared to the GC, in which responses tend to remain more prescriptive and generic (“I have to stay focused”), in the EG the selection appears more procedural and situational, with explicit references to cues and priorities.

Theme 2 – Managing distractions and regaining focus after an error (attentional reset)

A second core theme concerns the ability to recognize loss of concentration and quickly regain focus, especially

after errors, ineffective choices, or emotional interference. EG athletes report an increase in metacognitive awareness (“I notice it sooner”), accompanied by a reduction in the time needed to return to the task. Davide (EG, wing) explicitly describes this transition: “I still get distracted, but I notice it sooner and get back into the game right away; before, I would be out of it for two plays.” Andrea (EG) links this process to error management: “If I make a mistake, I think about it, but then I say to myself, ‘next play,’ and get back on defense.”

Systematic observations confirm a consistent behavioral change: in the final sessions of the workshop, the EG shows a decrease in episodes of disorganization following an error (e.g., delays in returning to defense, protests, hesitation, or “freezing” after a wrong choice) and an increase in the speed with which the athlete realigns with the next task. In the CG, on the contrary, sequences of error persistence (repetition of impulsive or ineffective choices after a negative event) and greater vulnerability to situational distractions (noise, provocation, frustration) were more frequent, without any declared recovery strategies.

Theme 3 – Interference control and inhibition of impulsive responses under pressure

A particularly recurring theme in EG concerns impulse control and the ability to suspend automatic responses under time and competitive pressure. Athletes describe a change in their “impulsivity threshold”: they do not eliminate the speed typical of the game, but they acquire the ability to introduce a micro-space of control (“half a second”) before the action, especially in situations requiring rapid decision-making. Matteo (EG) reports: “In exercises with little time, I have learned not to shoot immediately: I wait half a second and often see the pass,” while Simone (EG, center) adds: “I have retained the habit of controlling myself; I don’t force it if there is no advantage.”

The observations support this theme by showing, in EG, higher decision-making quality in critical phases (end of quarter, quick transitions, throw-ins) and a reduction in hasty actions in response to situational stress (aggressive defense, reduced time). In particular, the choice of functional solutions (extra pass, reversal, attack of the real advantage) appears to be more frequent than automatic solutions (immediate shot, individual forcing) observed more frequently in the GC under the same conditions.

Theme 4 – Emergence of attentive routines and self-regulation strategies (breathing, keywords, rituals)

A fourth thematic core concerns the emergence of attentive self-regulation strategies, described as simple and repeatable tools for stabilizing focus and containing emotional interference. The EG reports practices such as conscious breathing, the use of focusing keywords, and pre-action rituals. Francesco (EG) states, “When I feel like I’m getting out of control, I take a breath and say to myself, ‘simple,’” while Giorgio (EG) highlights the adoption of a stable routine in free throws: “I always do the same thing on free throws, so I don’t think too much.”

This theme is relevant because it indicates not only a change in performance but also a transformation in self-

regulation skills: athletes describe concrete and applicable strategies related to task cues (moments of pressure, interruptions, free throws, mistakes). In the CG, such strategies are less frequently explicit; when present, they tend to be formulated in a generic way (e.g., “I try to calm down”), without structured operational routines.

Theme 5 – Transfer situated in competition situations and functional generalization

The theme of transfer appears in the EG formulated in a situational way, with references to specific and recognizable contexts of competitive performance. Athletes describe an improvement in detecting changes in the context (e.g., defensive adjustments, changes in pace, external pressures) and in quickly updating the rule of action, recalling the similarity with exercises with variable constraints. Nicola (EG, point guard) states: “In competition, I notice when the defense changes sooner, as in exercises with changing rules,” while Alessandro (EG) links selective attention to the ability to filter out external interference: “Even if the crowd is shouting or someone is talking to me, I stay focused on the game.”

Observations in context confirm that EG adapts better to situational demands: in the final stages of the course, there is greater continuity of focus in transitions, more readiness in defensive reorganization, and greater adherence to instructions in exercises with variable objectives. In contrast, in the CG, the transfer is expressed mainly as intent (“I need to concentrate more”) rather than as an operational change, and observations indicate greater susceptibility to interference at critical moments.

Overall, the qualitative results indicate that the workshop promoted a change in the SG that cannot be reduced to a generic “greater concentration” but can be traced back to specific processes of attentional control: (a) prioritization of relevant stimuli, (b) filtering of irrelevant stimuli and resistance to interference, (c) inhibition of impulsive responses under pressure, (d) rapid recovery of focus after error, (e) consolidation of self-regulation strategies and their transfer to the competition. This profile is consistent with the improvement observed in the Stroop test, as it describes a functional enhancement of inhibition and attentive selection processes in conditions of information conflict, with concrete and observable manifestations in game behavior.

Discussion

The results of the study indicate that a basketball laboratory designed to systematically increase perceptual-decision complexity—through informational, temporal, regulatory, and spatial constraints—is associated with a significant improvement in Stroop interference control and consistent experiential and behavioral changes. The extent of the quantitative improvement (18–20% reduction in interference in the EG, with significant time \times group interaction) is consistent with the idea, supported by recent literature, that open-skill sports practice and, above all, repeated exposure to cognitively demanding tasks, can promote superior performance in the domains of executive functions related to inhibition and attentional control. Evidence from comparative studies between open-skill and

closed-skill athletes (Koch et al., 2021) and meta-analytic syntheses that attribute an average advantage to open-skill sports in the expression of executive functions (Heilmann et al., 2022), suggesting that it is not “sport” itself that produces the effect, but the quantity and quality of attentional-decision-making demands imposed by the environment. In theoretical terms, the Stroop outcome can be interpreted as an improvement in the ability to maintain the relevant rule and inhibit the automatic response in conditions of conflict, a process that in neurocognitive literature is considered a robust indicator of interference control and cognitive inhibition (Scarpina & Tagini, 2017).

Integration with qualitative data reinforces the causal interpretation and, above all, clarifies the possible mechanisms of transfer from the laboratory to the sporting context. The interviews show that the athletes in the experimental group do not describe a generic “being more focused,” but report a change in the management of information conflict: selecting “the right signal,” filtering out noise (audience, opponents, previous error), interrupting impulsive choices, and quickly updating the rule of action when the exercise changes. This narrative profile is consistent with the ecological-dynamic hypothesis that learning emerges from the coupling of information and movement and is enhanced when the task reproduces the informational and decision-making demands typical of competition (Representative Learning Design). In other words, in the laboratory, the athlete was repeatedly exposed to conditions in which performance depended on inhibiting automatisms (e.g., shooting “as soon as free,” attacking “as soon as I receive”) and updating attentional priority under constraints (reduced time, restricted space, variable rules), i.e., exactly the type of situation in which interference control becomes functional. The use of small-sided games with high decision-making density is particularly plausible as a “vehicle” for this effect: in the literature on small-sided games in team sports, the manipulation of space, number of players, and rules is indicated as a lever for modulating perceptual load and decision making, making training more representative and transferable (Clemente et al., 2021; Ramos et al., 2020). It is important to emphasize that the laboratory did not isolate cognition from motor skills but incorporated it into technical-tactical tasks, a choice consistent with recent methodological indications that point to interpretative limitations of cognitive tests when they are not linked to contexts of action and recommend integrated approaches in the cognitive assessment of athletes (Susanto et al., 2024a).

A crucial point concerns the validity of the Stroop test as an outcome in sport. The Stroop does not measure sport-specific skills, but offers a standardized measure of interference control useful for detecting changes in basic executive processes, which research links to performance in competitive contexts where time pressure, stress, and mental fatigue increase the risk of automatic and dysfunctional responses. Precisely for this reason, the convergence between Stroop improvement and qualitative reports (reduction in impulsivity, recovery of focus after error, faster selection of signals) is a strong element: it mitigates the classic criticism of the poor ‘ecological validity’ of neuropsychological tasks and suggests that, in this case, the test has functioned as a sensitive indicator of a change that athletes also recognize in the game. This interpretation is in line with recent research on inhibition in sport, which

highlights a bidirectional relationship between sports practice and inhibitory control and emphasizes that more experienced athletes tend to perform better in inhibition tasks, especially when the sporting context requires quick decisions and control under pressure (Albaladejo-García et al., 2023; Rahimi et al., 2022). Furthermore, the emergence of attentional routines and self-instructions (breathing, keywords, pre-action rituals) may be linked to attention stabilization and pressure management, especially when routines are simple, repeatable, and linked to task-relevant cues.

In terms of application, the results suggest that the effectiveness of the workshop stems from a combination of three factors: intensity of exposure (two sessions per week for six months), intentional design of constraints, and progression of complexity (from few constraints to competing constraints and changes during action). This triad is also consistent with the literature on physical activity interventions and executive functions in childhood: the most recent meta-analyses indicate that structured and continuous programs can produce improvements in executive functions in children and adolescents, although the effect depends on the “dose” and quality of the task (e.g., cognitive demand and engagement) rather than on the mere volume of activity (Li et al., 2025). At the same time, a rigorous discussion must recognize the methodological limitations typical of an experiment: the absence of full randomization, the possible influence of contextual factors (coaching style, cohesion, motivation), the use of a single main test for executive function (Stroop), and the need to include complementary measures in future studies (e.g., motor inhibition tasks such as stop-signal, more ecological assessments of decision making, and indicators of performance in competition). Furthermore, recent literature calls for avoiding a “dogmatic” application of the constraints-led approach: the quality of the effect depends on how constraints are selected and their link to the information actually available in competition; poorly calibrated constraints can increase noise and frustration without improving the functionality of perception (Bobrownicki et al., 2023). In summary, the present study supports the idea that training designed as a cognitive learning environment can produce measurable benefits on selective attention, but also suggests that such benefits require careful instructional engineering of the task, controlled progression, and a broader set of measures to fully describe the transfer to performance.

Conclusion

In conclusion, the results of this study support the effectiveness of a six-month basketball laboratory, structured according to principles of representative design and systematic manipulation of constraints, in promoting improved selective attention and interference control in athletes under 17. Quantitatively, the reduction in the Stroop interference index in the experimental group, together with the significant time \times group interaction, indicates an enhancement of cognitive inhibition processes and maintenance of the relevant rule in conditions of stimulus-response conflict. Qualitatively, the triangulation between interviews and observations documents convergent changes in attentional and self-regulatory strategies: athletes report a more efficient hierarchy of informational stimuli, a greater ability to filter situational interference (noise,

provocations, outcomes of previous actions), faster attentional realignment times after errors, and more stable control of impulsive responses in high-pressure situations, with examples of transfer reported in competition situations (adaptation to defensive changes and management of critical phases). Overall, the integration of the results suggests that high-density information training interventions, incorporated into technical-tactical exercises and not decontextualized from the action, can contribute to the development of executive components functional to performance in open-skill sports in adolescence. Looking ahead, further research will be needed to consolidate the robustness of these findings through more controlled experimental designs, the use of complementary cognitive batteries, and the inclusion of ecological indicators of decision-making and competition performance (Di Palma et al., 2025), in order to clarify the degree of generalizability, mediating mechanisms, and the optimal “dose” of the intervention.

Ethics Approval and Consent to Participate

The study was approved by the University of Naples Parthenope (DiSMMeB, Prot. No. 88779/2025). The research was conducted in accordance with established ethical standards for research involving human participants. Informed consent was obtained from all participants and/or their legal guardians prior to participation.

Conflict of Interest

The authors declare no conflicts of interest.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

AI Transparency Statement

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Покращення селективної уваги в юнацькому баскетболі: когнітивні та фізіологічні результати репрезентативної тренувальної інтервенції

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 3 табл., 26 джерел.

Цілі. Дослідження мало на меті оцінити ефективність програми тренувань з баскетболу, розробленої для покращення селективної уваги та контролю інтерференції у спортсменів вікової категорії до 17 років шляхом підвищення атенційного навантаження під час практичних занять.

Матеріали та методи. У дослідженні було застосовано експериментальний дизайн зі змішаними методами. У дослідженні взяли участь сорок кваліфікованих баскетболістів віком 16 років, які були розподілені на експериментальну (n = 21) та контрольну (n = 19) групи. Селективна увага оцінювалася за допомогою тесту Струпа (методики словесно-колірної інтреференції) під час перед- та постінтервенційної фаз дослідження. Якісні дані зібрано шляхом проведення систематичних спостережень та напівструктурованих інтерв'ю зі спортсменами та тренерами. Експериментальна інтервенція включала програму баскетбольних тренувань із систематичним маніпулюванням обмеженнями завдань та впровадженням екологічно репрезентативних вправ, спрямованих на підвищення вимог до уваги.

Результати. Після шести місяців інтервенції в експериментальній групі спостерігалось значуще зниження індексу інтерференції Струпа порівняно з контрольною групою. Крім того, спортсмени експериментальної групи продемонстрували суттєве скорочення часу реакції та зменшення кількості помилок в інконгруентних умовах тесту. Якісні дані вказали на розвиток ефективніших атенційних стратегій, покращення здатності фільтрувати нерелевантні подразники, посилення контролю імпульсивних реакцій та швидше відновлення концентрації уваги у стресових ігрових ситуаціях.

Висновки. Результати дослідження свідчать про те, що програма баскетбольних тренувань, заснована на систематичному маніпулюванні практичними обмеженнями та використанні екологічно валідних вправ, може ефективно підтримувати розвиток селективної уваги та контролю інтерференції у підлітків-спортсменів. Такі підходи можуть сприяти покращенню процесу ухвалення рішень та результативності у командних видах спорту, що вимагають застосування відкритих навичок.

Ключові слова: когнітивні функції, селективна увага, контроль інтерференції, баскетбол, ухвалення рішень, когнітивне тренування.

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