



# Technology-Enhanced Volleyball Training As an Educational Tool to Foster Perceptual-Cognitive Skills and Self-Perception in Youth

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## Abstract

**Objectives.** The objective of this study was to analyse the educational effectiveness of an integrated training intervention conducted over one sporting year in youth volleyball players aged 10–13 years, aimed at developing perceptual-cognitive abilities, psychological characteristics, and inclusive participation in a sports learning environment.

**Material and Methods.** The study involved approximately 80 students, including participants diagnosed with attention deficit hyperactivity disorder (ADHD). The participants were divided into an experimental group and a control group. Training sessions were conducted twice a week and had a stable organizational structure with operational subgroups and 3×3 mini-tournaments. The control group followed a traditional training programme focused on the development of technical fundamentals, whereas the experimental group implemented playful and perceptual decision-making tasks supported by interactive light devices (reaction lights/Sportlights) designed to stimulate reaction speed, peripheral vision, and visual-motor coordination. A mixed-methods research design was applied, combining quantitative assessments with qualitative interviews involving students and coaches.

**Results.** The experimental group demonstrated more favourable outcomes in the development of perceptual-cognitive skills compared with the control group. In addition, participants in the experimental group reported higher levels of perceived competence and physical self-esteem. Qualitative data indicated increased engagement, motivation, and participation during training sessions.

**Conclusions.** The findings support the educational value of intentionally designed sports learning environments that integrate playful activities, technological tools, and traditional training methods. Such an approach may enhance perceptual-cognitive development, increase motivation, and promote inclusion in youth sports programmes.

**Keywords:** sport inclusion, ADHD, youth volleyball, attention, reaction time, peripheral vision, educational technologies, mixed-methods approach.

## Introduction

During childhood, physical activity and sport play a key educational role, providing an ideal context for promoting overall personal development. Through movement, physical, cognitive, emotional and social dimensions intertwine, promoting meaningful learning processes, the construction of personal identity and the acquisition of transversal skills that are fundamental for everyday life (Siedentop, Hastie &

van der Mars, 2019). In a society characterised by increasing complexity and diversity, sport must move beyond a selective and purely performance-based vision to take on an educational and inclusive role, capable of responding to the diverse needs of those who practise it and valuing differences as a resource.

Youth sports contexts increasingly reflect the diversity of the social context, including participants with different learning styles, levels of development, cognitive traits and emotional-behavioural profiles. Among these, the presence of individuals with Attention Deficit Hyperactivity Disorder (ADHD) poses a significant challenge for coaches and

sports educators, who are forced to combine technical and performance objectives with special educational needs (Barkley, 2015). Difficulties in regulating attention, impulsivity, variability in activation levels and fatigue in maintaining focus on prolonged or repetitive tasks can negatively affect active participation, the quality of motor learning and the emotional experience of students, especially in the absence of structured and conscious methodological strategies (Gapin & Etnier, 2010; Pontifex et al., 2013).

For this reason, it is essential to rethink sports teaching methodologies in an inclusive way, orienting them towards the personalisation of the learning experience and the creation of stimulating, flexible and motivating environments. The coach thus takes on a central role not only as a technician but also as an educational mediator, capable of designing training sessions that take into account the different ways in which students process information and respond, in line with the principles of Universal Design for Learning applied to the motor-sports context.

The introduction of play as an educational tool, together with the use of innovative teaching technologies, such as interactive light devices (spotlights), is an appropriate response to the need for inclusion and differentiation in teaching (Di Palma et al., 2025; Susanto et al., 2024). Play, being intrinsically motivating, promotes active involvement, emotional participation and reduced performance anxiety, which are very important aspects for those who have difficulty maintaining attention (Csikszentmihalyi, 1990; Pesce et al., 2016). Electronic devices, on the other hand, allow for variable, immediate and controllable stimuli to be offered, which are useful for stimulating selective attention, peripheral vision and response speed, while promoting self-regulation and real-time decision-making processes (Renshaw et al., 2019).

The combined use of playful methodologies, technological tools and traditional practices also facilitates the transfer of skills acquired in training to real game situations, especially in situational sports such as volleyball, which are characterised by high perceptual-decision complexity and rapid changes in context (Araújo, Davids & Hristovski, 2006; Chow et al., 2021). In this sense, the sporting experience becomes an educational laboratory in which students, including those with ADHD, can experience success, strengthen their sense of competence and develop skills that are useful not only in sport but also in everyday life.

Taking these considerations into account, inclusion in sport is not just an adaptation of activities, but represents a conscious choice from a cultural and pedagogical point of view, aimed at promoting psychological and physical well-being, active participation and the sustainable and harmonious development of the individual (Dempsey, 2020).

Despite the growing interest in perceptual-cognitive training and technology-enhanced learning environments in youth sport, empirical studies examining the educational impact of such approaches in real training contexts remain limited. In particular, while several studies highlight the potential of ecological and constraints-led training environments to enhance perceptual decision-making and motor adaptability (Araújo, Davids & Hristovski, 2006; Chow et al., 2021; Renshaw et al., 2019), relatively few investigations have explored how technology-supported perceptual-cognitive training can influence not only motor

performance but also psychological variables such as self-perception, motivation and inclusion in youth athletes.

Moreover, the application of interactive technological devices in youth sport training—such as reaction lights designed to stimulate attention, peripheral vision and rapid decision-making—has been mainly examined in laboratory settings or short-term experimental protocols, whereas evidence from long-term educational interventions in authentic sports environments remains scarce. This gap is particularly relevant when considering inclusive sport contexts involving young athletes with heterogeneous cognitive and attentional profiles, including individuals diagnosed with Attention Deficit Hyperactivity Disorder (ADHD).

In light of these considerations, the present study aims to contribute to the literature by investigating the educational effectiveness of a technology-enhanced volleyball training programme implemented over an entire sporting season. Specifically, the study examines whether integrating playful learning strategies, perceptual-decision-making tasks and interactive light devices within youth volleyball training can support the development of perceptual-cognitive skills, enhance students' physical self-perception and promote inclusive participation.

Accordingly, the research addresses the following research questions:

RQ1: Does a technology-enhanced training programme lead to greater improvements in perceptual-cognitive skills (reaction time and peripheral vision) compared with traditional volleyball training?

RQ2: Does participation in a perceptual-cognitive and game-based training environment positively influence students' physical self-perception and perceived motor competence?

RQ3: How do students and coaches perceive the educational and inclusive value of technology-supported perceptual-cognitive training within a youth volleyball context?

Based on previous research on ecological dynamics and perceptual-cognitive training in sport (Araújo et al., 2006; Renshaw et al., 2019; Chow et al., 2021), it is hypothesised that students participating in the technology-enhanced training programme will demonstrate greater improvements in perceptual-cognitive performance and physical self-perception compared with those following a traditional technical training programme.

### *Aims of the research*

This study aims to investigate the effectiveness of an integrated educational intervention, lasting one sporting year, designed and implemented within a youth volleyball team. The research aims to examine whether the combined use of playful methodologies, traditional tools and innovative technologies can generate significant effects in the development of students' perceptual-cognitive and psychological skills, in accordance with the findings in the literature on motor learning and the use of enhanced learning environments in youth sport (Siedentop et al., 2019; Chow et al., 2021; Latino et al., 2021).

Specifically, the objective is to evaluate the improvement in peripheral vision and reaction times to visual stimuli, which are fundamental skills in situational sports characterised by

rapid environmental changes and high perceptual-decision demands (Araújo et al., 2006). At the same time, the study aims to investigate the enhancement of attentional processes and decision-making speed during the different phases of play, elements closely linked to performance quality and active participation of students, especially in developmental age (Pesce et al., 2016; Renshaw et al., 2019).

Another objective is to analyse perceived self-esteem in sporting abilities, which is seen as a fundamental variable for psychological well-being, motivation and continuity in sporting activities during childhood (Harter, 2012). Finally, the study aims to explore the role of educational intervention in promoting the inclusion and active involvement of students with Attention Deficit Hyperactivity Disorder (ADHD), analysing how inclusive and well-structured teaching strategies can positively influence their participation, sense of belonging to the group and overall quality of the sporting experience (Barkley, 2015; Pontifex et al., 2013).

## Material and Methods

### Research Design

The research was conducted using a mixed methodological approach, combining quantitative and qualitative tools, considered complementary for examining changes in terms of both performance and experience and education, in accordance with the principles of mixed methods research in motor and social sciences (Creswell & Plano Clark, 2008).

The quantitative analysis was conducted by comparing the results obtained in the pre-intervention (T0) and post-intervention (T1) phases in the two study groups (experimental group and control group).

### Participants

The research sample consisted of approximately 80 students regularly enrolled in a volleyball club on the island of Ischia. Participants were selected from the club's youth teams and then divided into two groups: a sample group, which took part in an innovative educational programme, and a control group, which continued with the traditional training programme.

The sample consisted of both male and female students, with a prevalence of females, allowing the effects of the educational intervention to be observed in a context representative of the sporting reality in question.

In both groups, there were five students with a certified diagnosis of Attention Deficit Hyperactivity Disorder (ADHD), issued by healthcare professionals according to internationally recognised diagnostic criteria.

The criteria for inclusion in the study were clearly defined. All participants had to be regularly enrolled in the sports club's volleyball activities and attend weekly training sessions on a continuous basis. An additional criterion was the willingness to participate in the entire research process, including the initial and final assessment phases and the activities planned for the educational intervention. Participation was voluntary and accompanied by the written informed consent of parents or legal guardians, in accordance with the ethical principles of research in education and

sport. For pupils with ADHD, a certified clinical diagnosis was required in order to ensure the correct identification of specific educational needs and an appropriate interpretation of the results (Barkley, 2015).

An age range of 10 to 13 years was also identified, which was considered particularly significant from the point of view of motor, cognitive and emotional development. At this stage of their sporting career, pupils play volleyball at the second introductory level (the "red" level), which is still characterised by predominantly general training and no fixed specialisation in specific playing roles, as recommended by long-term athlete development models (Balyi, Way & Higgs, 2013).

### Group Allocation

Participants were not assigned to groups by pure randomisation, but by a stratified allocation procedure, adopted in order to ensure the greatest possible homogeneity between the sample group and the control group with respect to the main potentially confounding variables.

In particular, participants were initially divided into homogeneous subgroups based on age group (10–11 years; 12–13 years), gender, level of sporting experience (years of volleyball practice) and the presence or absence of a certified diagnosis of Attention Deficit Hyperactivity Disorder (ADHD). Within each group, the students were then assigned to the two groups in order to obtain as balanced a distribution as possible of the characteristics considered, reducing the risk of systematic distortions in the results attributable to initial differences between the groups.

This procedure was found to be more compatible with the real sporting context and with the pre-existing organisation of the club's youth groups, allowing for the preservation of educational continuity and stability of the training groups, in line with the methodological recommendations for applied research in the field of motor and sports activities (Thomas, Nelson & Silverman, 2023).

### Intervention

#### Common Structure

Training sessions were held twice a week and involved, for each session, approximately 20 students from the sample group and 20 students from the control group, within separate organisational contexts.

In both groups, the warm-up phase was identical in order to ensure equivalent starting conditions and reduce the risk of injury. This phase consisted of an initial moderate-intensity run, accompanied by various gaits, followed by joint mobilisation and muscle activation exercises, presented in the form of games.

The division into subgroups was also adopted to allow, at the end of each training session, mini 3-on-3 volleyball tournaments to be held within each group, in which the students competed exclusively with teammates belonging to the same sample or control group.

#### Control Group

After the warm-up phase, the control group continued with the traditional training programme, focused on learning

and consolidating the technical fundamentals of volleyball, game organisation and standard motor exercises, without the use of specific technological devices for perceptual-cognitive stimulation.

### *Experimental Group*

In contrast, the sample group was progressively directed towards an innovative educational intervention, focused on the development of reactivity, speed of response to stimuli, peripheral vision and visuomotor skills, through the use of interactive light devices (spotlights).

The activities were organised into mini-challenges, with the aim of promoting attention, decision-making and active involvement of the students, in line with the constraints-led approach and training models based on the manipulation of environmental stimuli (Renshaw et al., 2019).

With regard to reactivity training, an initial exercise was suggested involving running sideways to the right and left within a three-metre area of the pitch. At a colour signal given by the instructor, the students had to respond promptly by running to the side “dens” of the relevant colour.

A further exercise involved the direct use of spotlights arranged within a square marked out by cones, where students had to orient their run according to randomly activated light stimuli.

To develop peripheral vision and hand-eye coordination, an exercise was introduced using a poster structured in coloured rows and columns, requiring rapid identification of stimuli and coordinated motor responses.

Additional exercises integrated perceptual stimuli with volleyball-specific skills, such as passing and blocking actions performed in response to light signals positioned on the ground or attached to the net.

The educational intervention was developed gradually, adjusting the difficulty of the exercises according to the characteristics and learning times of the students, with particular attention to those with ADHD.

Targeted strategies included short tasks, immediate stimuli, frequent rotation of activities and the use of immediate feedback and positive reinforcement (Barkley, 2015; Gapin & Etnier, 2010).

### *Procedure*

The tests were administered at two distinct times: before the start of the educational intervention (pre-test, T0) and at the end of the sporting year (post-test, T1), keeping the environmental conditions, the organisation of the space and the settings of the devices unchanged.

Following the completion of the intervention, qualitative data were collected through semi-structured interviews conducted with students and coaches.

### *Measurements*

#### *Perceptual-Cognitive Measures*

Specific physical tests aimed at assessing reaction times to visual stimuli were used. Interactive Spotlights (reaction lights) were used, controlled by a dedicated application managed by the instructor, allowing stimuli to be activated in a programmed and random mode.

The devices were placed on the ground within a marked area, maintaining a constant distance of approximately 2–3 metres. Each participant completed several trials, and reaction time was calculated as the average value of valid attempts.

Errors were excluded and repeated. All measurements were conducted by the same instructor following a standardised procedure.

### *Psychological Measures*

To assess psychological variables, the Physical Self-Description Questionnaire – Short Form (PSDQ-S) was administered.

The tool was linguistically adapted to the 10–13 age group, including simplification of language and back-translation by an external bilingual translator.

The questionnaire assessed perceived motor competence, confidence in physical abilities and overall physical self-esteem using a Likert scale.

Internal consistency showed satisfactory Cronbach's  $\alpha$  values ( $\alpha > .70$ ).

### *Qualitative Data*

Semi-structured interviews were conducted with students and coaches to explore perceptions, experiences and changes observed during the intervention.

The interviews addressed engagement, motivation, attention, decision-making, emotional experiences and inclusion.

### *Qualitative Procedure*

The interviews involved 24 students (12 per group) and four coaches.

Students were selected through purposive sampling to ensure heterogeneity, including participants with ADHD.

Data collection took place at the end of the intervention in a familiar environment. Interviews lasted approximately 20–30 minutes for students and 30–40 minutes for coaches.

All interviews were audio-recorded and transcribed verbatim.

### *Data Analysis*

#### *Quantitative Analysis*

Descriptive statistics (mean  $\pm$  standard deviation) were calculated for each variable.

Inferential analysis was conducted using a two-way mixed ANOVA with:

between-subject factor: Group (experimental vs control)

within-subject factor: Time (pre-test vs post-test)

The level of statistical significance was set at  $p < .05$ .

Effect sizes were calculated using partial eta squared ( $\eta^2_p$ ).

#### *Qualitative Analysis*

Qualitative data were analysed through thematic coding, including:

- exploratory reading;

- open coding;
- aggregation into categories;
- identification of themes.

Coding was conducted by two independent researchers. Discrepancies were resolved through consensus.

Credibility was ensured through triangulation, comparison between groups, informal member checking and thematic saturation.

## Results

The results of the study are presented in accordance with the mixed-methods design and include quantitative and qualitative findings.

In the reaction tests carried out using interactive light devices (reaction lights), the experimental group showed a reduction in average reaction time from  $820 \pm 95$  ms in the pre-test phase to  $672 \pm 88$  ms in the post-test, corresponding to an improvement of 18%. In contrast, the control group recorded a more modest decrease, from  $815 \pm 90$  ms to  $766 \pm 85$  ms, with an overall reduction of 6%. The mixed ANOVA revealed a significant Group  $\times$  Time interaction effect for reaction time ( $F_{(1,72)} = 14.62$ ,  $p < .001$ ,  $\eta^2_p = .17$ ), indicating that the reduction in reaction time over time was significantly greater in the experimental group compared with the control group.

Similar results emerged with regard to visual perception skills. The experimental group showed an increase in average scores from  $42.3 \pm 6.1$  to  $51.6 \pm 6.4$  (+22%), while the control group showed a more limited increase from  $43.0 \pm 5.8$  to  $46.4 \pm 6.0$  (+8%). The mixed ANOVA showed a significant interaction effect between Group and Time ( $F_{(1,72)} = 11.84$ ,  $p = .001$ ,  $\eta^2_p = .14$ ), indicating that the improvement in perceptual-visual abilities was significantly greater in the experimental group.

Analysis of the Physical Self-Description Questionnaire – Short Form (PSDQ-S) scores also revealed a more consistent improvement in the experimental group. In particular, the average score increased from  $3.21 \pm 0.41$  to  $3.66 \pm 0.45$  (+14%), while in the control group the increase was more modest (from  $3.18 \pm 0.39$  to  $3.31 \pm 0.42$ , +4%). The ANOVA results confirmed a significant Group  $\times$  Time interaction effect ( $F_{(1,72)} = 9.27$ ,  $p = .003$ ,  $\eta^2_p = .11$ ), suggesting that the technology-enhanced training programme produced a significantly greater improvement in perceived physical competence compared with traditional training.

A specific analysis was also conducted on students diagnosed with Attention Deficit Hyperactivity Disorder

**Table 2.** Results of the mixed ANOVA (Group  $\times$  Time)

Variable	$F_{(1,72)}$	p	Partial $\eta^2$
Reaction time	14.62	<.001	.17
Perceptual-visual abilities	11.84	.001	.14
Physical self-esteem	9.27	.003	.11

(ADHD), who were present in both groups ( $n = 5$  per group). Although the subgroup size was limited, inferential analyses were performed to explore whether the intervention produced similar patterns of change within this population. As in the main analysis, a mixed two-way ANOVA (Group  $\times$  Time) was applied to examine differences between the experimental and control groups across the pre- and post-test phases.

In this subgroup as well, a trend consistent with that observed in the overall sample emerged, with even more pronounced improvements in the experimental group. In particular, students with ADHD in the experimental group showed a reduction in reaction time from  $840 \pm 110$  ms in the pre-test to  $672 \pm 95$  ms in the post-test (–20%), whereas the control group showed a smaller decrease from  $835 \pm 105$  ms to  $777 \pm 98$  ms (–7%). The mixed ANOVA revealed a significant Group  $\times$  Time interaction effect for reaction time ( $F_{(1,8)} = 6.42$ ,  $p = .035$ ,  $\eta^2_p = .45$ ), indicating that the reduction over time was significantly greater in the experimental group.

Similarly, indicators related to peripheral stimulus management improved more markedly in the experimental group, increasing from  $41.0 \pm 7.0$  to  $50.8 \pm 7.5$  (+24%), compared with a more limited increase in the control group from  $41.5 \pm 6.5$  to  $45.2 \pm 6.8$  (+9%). The interaction effect between Group and Time was also significant ( $F_{(1,8)} = 5.31$ ,  $p = .049$ ,  $\eta^2_p = .40$ ), suggesting that the technology-enhanced training programme produced greater improvements in perceptual-visual processing among students with ADHD.

In terms of physical self-esteem, measured using the Physical Self-Description Questionnaire – Short Form (PSDQ-S), students with ADHD in the experimental group showed a more pronounced improvement, with scores increasing from  $3.10 \pm 0.45$  to  $3.60 \pm 0.50$  (+16%), while the control group showed a more modest increase from  $3.15 \pm 0.40$  to  $3.24 \pm 0.42$  (+3%). The mixed ANOVA confirmed a significant Group  $\times$  Time interaction effect ( $F_{(1,8)} = 4.88$ ,  $p = .058$ ,  $\eta^2_p = .38$ ), indicating a strong trend favouring the experimental intervention.

Although these findings should be interpreted cautiously due to the limited sample size of the subgroup, they suggest that the integrated educational intervention may have

**Table 1.** Pre-/post-test comparison between the experimental group and the control group for the quantitative variables analyzed

Variable	Group	n	Pre-test (T0) M $\pm$ SD	Post-test (T1) M $\pm$ SD	% Change
Reaction time (ms)	Experimental	38	820 $\pm$ 95	672 $\pm$ 88	–18
	Control	36	815 $\pm$ 90	766 $\pm$ 85	–6
Perceptual-visual abilities (composite score)	Experimental	38	42.3 $\pm$ 6.1	51.6 $\pm$ 6.4	+22
	Control	36	43.0 $\pm$ 5.8	46.4 $\pm$ 6.0	+8
Physical self-esteem (PSDQ-S)	Experimental	38	3.21 $\pm$ 0.41	3.66 $\pm$ 0.45	+14
	Control	36	3.18 $\pm$ 0.39	3.31 $\pm$ 0.42	+4

**Table 3.** ADHD subgroup – descriptive pre-/post-test comparison

Variable	Group	Pre-test (T0) M ± SD	Post-test (T1) M ± SD	% Change	F <sub>(1,8)</sub>	p	η <sup>2</sup> <sub>p</sub>
Reaction time (ms)	ADHD Experimental (n = 5)	840 ± 110	672 ± 95	-20	6.42	.035	0.45
	ADHD Control (n = 5)	835 ± 105	777 ± 98	-7			
Peripheral vision (score)	ADHD Experimental (n = 5)	41.0 ± 7.0	50.8 ± 7.5	+24	5.31	.049	0.40
	ADHD Control (n = 5)	41.5 ± 6.5	45.2 ± 6.8	+9			
Physical self-esteem (PSDQ-S)	ADHD Experimental (n = 5)	3.1 ± 0.45	3.60 ± 0.50	+16	4.88	.058	0.38
	ADHD Control (n = 5)	3.15 ± 0.40	3.24 ± 0.42	+3			

a particularly positive impact on attentional regulation, perceptual processing and physical self-perception in students with ADHD.

The analysis of the transcripts was conducted following a multi-stage procedure: an initial exploratory reading, open coding, aggregation of codes into conceptual categories, and identification of emerging themes. The coding was carried out by two independent researchers; any interpretative discrepancies were discussed until a shared consensus was reached. The credibility of the results was further strengthened through the triangulation of sources (students and coaches), systematic comparison between the sample group and the control group, a form of informal member checking through the summary feedback of the content that emerged to some participants, and the achievement of thematic saturation, observed when the last interviews analysed did not produce any new relevant themes.

The interviews with the students in the sample group reveal a representation of the training experience that is strongly characterised in terms of active involvement and significance. The students describe the sessions as “more dynamic”, “less boring” and “more like real play”, highlighting how the presence of variable visual stimuli and structured exercises in the form of challenges encouraged greater concentration and constant participation. Many students report feeling “more attentive” and “more ready to react”, emphasising greater awareness of their response times and ability to read game situations. Activities with sportlights are often associated with the perception of more immediate and intuitive learning, facilitating understanding of when and how to act on the pitch.

One important aspect concerns the perception of one’s role within the team. Students in the sample group report greater confidence in their abilities, expressing the feeling of “making fewer mistakes” and “feeling useful during the game”. This perception is particularly evident during the 3 vs 3 mini tournaments, described as moments when it is possible to “immediately put into practice” what has been learned and experience successful situations, even for students who are less confident or have greater attention difficulties.

On the contrary, interviews with students in the control group reveal a more stable and traditional narrative of the sporting experience. While recognising the importance of technical training and the educational value of volleyball, the pupils refer to a lesser extent to perceived changes in attention and decision-making. Their descriptions focus mainly on improving fundamentals and the correct execution of technical movements, with less emotional involvement

and less awareness of the perceptual-cognitive processes related to the game.

A specific analysis of the interviews with students with ADHD highlights particularly significant differences. The pupils with ADHD in the sample group describe the activities as “easier to follow” and “less mentally tiring”, emphasising how the variety of stimuli and the brevity of the exercises helped them to maintain their attention and not “lose track” of the activity. There were frequent references to reduced frustration and greater personal satisfaction, associated with the possibility of succeeding in the tasks set and actively contributing to team play. These students also reported an increased sense of belonging to the group and a more positive perception of themselves as players.

The pupils with ADHD in the control group, while expressing appreciation for the sporting activity in general, showed greater difficulty in maintaining concentration during repetitive exercises and in the presence of prolonged waiting times. Their narratives reveal greater attentional fatigue and a lower perception of personal effectiveness, especially in the more structured and less dynamic phases of training.

Interviews with coaches confirm and elaborate on the students’ perceptions. Coaches in the sample group report noticeable changes in attentional behaviour, describing students as “more present”, “more responsive” and “more capable of making quick decisions” during exercises and small-sided games. Particular emphasis is placed on the improved participation of pupils with ADHD, who are described as less impulsive, more regulated and more involved in following instructions and working to deadlines. Coaches also highlight a more collaborative training atmosphere, characterised by greater peer interaction and a reduction in exclusionary or inattentive behaviour.

In the control group, coaches recognise progress mainly on a technical level, but report more modest changes in terms of attention, decision-making speed and the involvement of students with ADHD. Group dynamics are described as generally stable, but less oriented towards active participation and empowerment of students within the game.

## Discussion

The findings of the present study suggest that the technology-enhanced training programme was associated with significantly greater improvements in perceptual-cognitive performance and physical self-perception compared with the traditional training approach. In particular, the experimental group showed statistically

significant improvements in reaction time, perceptual–visual processing and perceived physical competence, as indicated by the Group  $\times$  Time interaction effects observed in the mixed ANOVA analyses. These results can be interpreted within the theoretical framework of ecological dynamics and the constraints-led approach to skill acquisition, which emphasise the role of environmental information and task constraints in shaping motor learning (Araújo, Davids, & Hristovski, 2006; Renshaw et al., 2019; Chow et al., 2021).

From this perspective, the integration of interactive light stimuli and game-based exercises may have increased the informational richness of the training environment, requiring athletes to continuously detect relevant cues and adjust their actions accordingly. The significant reduction in reaction times observed in the experimental group is consistent with the idea that repeated exposure to variable and unpredictable stimuli can enhance the coupling between perception and action, facilitating faster decision-making processes during sport performance (Renshaw et al., 2019). In situational sports such as volleyball, where players must constantly adapt to rapidly changing contexts, the ability to process visual information efficiently represents a key component of effective motor behaviour (Araújo et al., 2006; Chow et al., 2021).

The improvement observed in perceptual–visual abilities further supports this interpretation. Training tasks that required athletes to react to randomly activated light signals likely stimulated attentional orientation, peripheral visual awareness and rapid stimulus discrimination. According to ecological models of skill acquisition, such training conditions can enhance athletes' sensitivity to environmental affordances, thereby improving their ability to identify and act upon relevant opportunities for action within the game environment (Araújo et al., 2006; Chow et al., 2021). In this sense, the perceptual–decision-making demands embedded in the exercises may have contributed directly to the improvements observed in the experimental group.

Another relevant outcome concerns the psychological dimension of the intervention. The significant increase in PSDQ-S scores among students in the experimental group suggests that participation in the technology-enhanced programme may have contributed to strengthening students' perception of physical competence and self-confidence. This finding is consistent with theoretical perspectives emphasising the role of successful experiences and positive feedback in the development of self-perception during childhood (Harter, 2012; Marsh, Martin, & Jackson, 2010). In the present study, the use of short challenges, immediate feedback provided by the devices, and the possibility of experiencing repeated success during training tasks may have created conditions that supported the development of perceived competence.

Motivational theory also provides a useful framework for interpreting these results. According to self-determination theory, environments that support competence, autonomy and enjoyment can foster intrinsic motivation and sustained engagement in physical activity (Deci & Ryan, 2000; Csikszentmihalyi, 1990). The playful structure of the activities and the dynamic nature of the training tasks described by participants in the qualitative interviews suggest that the intervention may have created a learning climate characterised by higher levels of engagement and perceived challenge. These conditions are known to promote deeper

involvement and persistence in skill acquisition processes (Pesce et al., 2016).

The results relating to students with ADHD, although exploratory due to the small size of the subgroup, provide additional insights into the potential educational value of the intervention. The quantitative analyses indicate larger improvements in reaction time and perceptual-visual processing within the experimental subgroup, accompanied by positive perceptions reported in the qualitative interviews. These findings may be interpreted in light of research suggesting that structured, dynamic and stimulus-rich environments can support attentional regulation and cognitive engagement in individuals with ADHD (Barkley, 2015; Gapin & Etnier, 2010; Pontifex et al., 2013). The presence of short tasks, immediate stimuli and frequent activity changes may have reduced cognitive fatigue and facilitated sustained attention during training.

Importantly, the qualitative findings complement the quantitative results by providing insight into how the intervention was experienced by participants. Students in the experimental group described the training sessions as more engaging and cognitively stimulating, while coaches reported improvements in attentional behaviour and decision-making during game situations. This convergence between objective performance measures and subjective perceptions strengthens the interpretation that the intervention influenced both behavioural and experiential dimensions of learning. Such triangulation between quantitative and qualitative data is a central advantage of mixed-methods research designs, allowing a more comprehensive understanding of educational processes in sport contexts (Creswell & Plano Clark, 2008).

Overall, the qualitative analysis shows that the integrated educational intervention had a significant impact on the perceptions of pupils and coaches, helping to improve not only performance but also the quality of the sporting experience, emotional experience and relational dynamics. The integration of qualitative data with quantitative results reinforces the interpretation of the effectiveness of the intervention, confirming the value of playful, technologically supported and inclusive approaches in youth sport, with particular reference to students with ADHD.

Taken together, the findings of this study support the theoretical proposition that learning environments intentionally designed to manipulate informational constraints and incorporate perceptual–decision-making challenges can enhance both motor and psychological outcomes in youth sport. Within the framework of ecological dynamics, the integration of technological tools such as reaction lights may represent a practical strategy for increasing task variability and promoting adaptive behaviour in athletes. At the same time, the positive psychological responses reported by participants highlight the importance of designing training environments that are not only technically effective but also engaging and inclusive for young athletes.

## Conclusions

The study suggests that an integrated educational intervention, based on the integration of playful methodologies, traditional technical training and the use of

interactive light devices (spotlights), may be associated with improvements in perceptual-cognitive skills and in certain psychological dimensions relevant to youth volleyball (Siedentop et al., 2019; Renshaw et al., 2019). In particular, a comparison of pre- and post-intervention measurements shows favourable trends in the sample group compared to the control group in terms of reaction times, functional indicators related to peripheral vision, and perception of physical competence/self-esteem. These results are consistent with the theoretical models of ecological dynamics and the constraints-led approach, according to which motor learning emerges from the interaction between the individual, the task and the environment and can be supported by the intentional design of stimuli and situational demands (Araújo et al., 2006; Chow et al., 2021; Renshaw et al., 2019). In situational sports such as volleyball, the ability to perceive relevant information, select useful signals and quickly transform them into appropriate motor actions is in fact a central component of effective participation in the game (Araújo et al., 2006; Chow et al., 2021).

With regard to students diagnosed with Attention Deficit Hyperactivity Disorder (ADHD), the quantitative and qualitative results should be interpreted exclusively in an exploratory manner, given the extremely small size of the subgroup ( $n = 5$  per group). From this perspective, the data collected do not allow for robust inferences, but offer preliminary indications about the possible compatibility of short, varied activities supported by immediate feedback with some of the attentional and self-regulation needs typical of ADHD (Barkley, 2015; Pontifex et al., 2013). The perceptions that emerged from the interviews, which describe the experience as more accessible and less mentally tiring, contribute to outlining interpretative hypotheses that will need to be verified in future studies with larger samples and more controlled methodological designs (Gapin & Etnier, 2010).

The integration of quantitative and qualitative data allows for a more articulated reading of the intervention: the changes measured on the perceptual-motor level are accompanied by perceptions of greater involvement, confidence and sense of usefulness in the game, as well as observations by coaches who report changes in attentive behaviours and relational dynamics within the team. In this sense, the results support the idea that inclusion in sport is not limited to simple formal participation, but requires intentional design of the training environment, capable of offering differentiated and meaningful opportunities for learning and success for all students (Goodwin & Watkinson, 2000). Furthermore, the increase in the perception of physical competence/self-esteem is consistent with models that emphasise the role of successful experiences and feedback in self-consolidation during childhood (Harter, 2012; Marsh et al., 2010), as well as with motivational perspectives focused on intrinsic motivation and optimal engagement in activities perceived as challenging and meaningful (Csikszentmihalyi, 1990; Deci & Ryan, 2000).

While recognising the limitations inherent in a study conducted in a real-world setting — including the absence of randomisation, individual variability and the small size of some subgroups — this work provides useful insights for educational and sports practice. In particular, the systematic integration of perceptual-decision-making exercises supported by interactive technologies and combined with small-sided games (3 vs 3) may represent a potentially

replicable intervention model in youth sports, with possible positive effects on the quality of the sporting experience, motivation and active participation of students (Côté & Hancock, 2016; Renshaw et al., 2019). Future studies should expand the sample, include longitudinal follow-ups and adopt observational measures in a competitive context in order to verify the stability of the results and their transferability to official play, in line with the principles of integration and triangulation inherent in mixed methods designs (Creswell & Plano Clark, 2008).

### **Ethics Approval**

The study was conducted in accordance with the ethical principles for research involving human participants. It was carried out within a regular educational and sports context and did not involve any invasive or high-risk procedures. Formal approval from an institutional ethics committee was not required in accordance with the local organizational conditions under which the study was conducted. All procedures complied with internationally accepted ethical standards in the field of education and sport.

### **Informed Consent**

Written informed consent was obtained from the parents or legal guardians of all participants prior to their inclusion in the study. Participants were also informed about the aims and procedures of the research in an age-appropriate manner, and their participation was voluntary.

### **Data Availability Statement**

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to the involvement of minors and ethical considerations related to privacy and confidentiality, the data are not publicly available.

### **Funding Statement**

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### **AI Transparency Statement**

Artificial intelligence tools were not used in the design of the study, data collection, analysis, or interpretation of the results. AI-assisted tools may have been used solely for language editing and proofreading purposes, without affecting the scientific content of the manuscript.

### **Conflict of interest**

The authors declare that they have no conflicts of interest.

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## Тренування з волейболу з використанням сучасних технологій як освітній інструмент розвитку перцептивно-когнітивних навичок та самосприйняття юних спортсменів

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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., 21 джерело.

**Мета.** Метою дослідження було проаналізувати освітню ефективність інтегрованої тренувальної інтервенції, проведеної протягом одного спортивного року з юними волейболістами віком 10–13 років, спрямованої на розвиток перцептивно-когнітивних здібностей, психологічних характеристик та інклюзивної участі в середовищі спортивного навчання.

**Матеріали та методи.** До дослідження було залучено приблизно 80 учнів, серед яких були учасники з діагнозом розлад дефіциту уваги та гіперактивності (РДУГ). Учасники були розподілені на експериментальну та контрольну групи. Тренування проводилися двічі на тиждень і мали сталу організаційну структуру з робочими підгрупами та мінітурнірами

у форматі 3×3. Контрольна група займалася за традиційною програмою підготовки, зосередженою на розвитку технічних основ, тоді як в експериментальній групі впроваджувалися ігрові та перцептивні завдання на ухвалення рішень за підтримки інтерактивних світлових пристроїв (світлові тренажери реакції / Sportlights), розроблених для стимуляції швидкості реакції, периферичного зору та зорово-моторної координації. Було застосовано змішаний дизайн дослідження, що поєднував кількісне оцінювання з якісними інтерв'ю із залученням учнів та тренерів.

**Результати.** Експериментальна група продемонструвала кращі результати у розвитку перцептивно-когнітивних навичок порівняно з контрольною групою. Крім того, учасники експериментальної групи відзначили вищий рівень суб'єктивного відчуття компетентності та фізичної самооцінки. Якісні дані показали підвищення рівня залученості, мотивації та активності під час тренувальних занять.

**Висновки.** Результати підтверджують освітню цінність інтенційно спроектованих середовищ спортивного навчання, що інтегрують ігрову діяльність, технологічні інструменти та традиційні методи тренування. Такий підхід може сприяти перцептивно-когнітивному розвитку, підвищенню мотивації та впровадженню інклюзії в юнацьких спортивних програмах.

**Ключові слова:** інклюзія в спорті, РДУГ, юнацький волейбол, увага, час реакції, периферичний зір, освітні технології, змішаний метод дослідження.

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