

The importance of peripheral vision in young football players: a mixed-methods study conducted in a sports club in Naples

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ABSTRACT

The study evaluated the effectiveness of a visual-motor training program with interactive lights (Le Reactiva) in enhancing peripheral vision, physical self-efficacy, and collaboration in young soccer players (aged 8–16). Using a mixed-methods (quantitative-qualitative) design, 100 athletes were assigned to an experimental group (n = 50; training with lights) and a control group (n = 50; traditional training) for 12 weeks (3 sessions/week, 60 minutes), with activities differentiated by age group (8–10; 11–16). Quantitative measures included a peripheral reactivity test based on Le Reactiva, the Physical Self-Efficacy Scale for Children (PSES), and the Youth Sport Environment Questionnaire (YSEQ). The analysis showed a marked improvement in the experimental group compared to the control group: a 15–20% reduction in reaction time to peripheral stimuli (vs. <5% in the control group), an increase in physical self-efficacy of approximately +0.6 points on a scale of 1–5 (vs. +0.1), and an increase in team cohesion (YSEQ) in both the task component (+0.5) and the social component (+0.4) (vs. +0.1–0.2). Repeated measures ANOVA confirmed significant differences between groups for all variables ($p < .01$), while the group \times age group interaction was not significant ($p > .05$), suggesting a cross-sectional effectiveness of the intervention in the two groups considered. Qualitative data converge in describing greater spatial awareness, decision-making speed, motivation, and cohesion in the experimental group. Overall, training with interactive lights appears to be a promising strategy for integrating perceptual-motor development and psychosocial dimensions into youth soccer training programs.

KEYWORDS

Peripheral Vision; Young Footballers; Self-Efficacy; Collaboration; Smart Lighting

1. INTRODUCTION

In youth football, athlete training cannot ignore the harmonious development of motor, cognitive, and social-relational skills. Perceptual skills, particularly peripheral vision, are often overlooked in training programmes despite being essential for developing well-rounded and aware players.

Peripheral vision is the ability to perceive visual stimuli outside the central field of vision. This allows athletes to monitor the game context without constantly turning their heads or eyes. In a dynamic sport such as football, this skill is crucial for identifying opportunities, anticipating opponents' movements, and making optimal decisions under pressure (Gonçalves et al., 2021).

Training peripheral vision during pre-adolescence enables the development of perceptual-motor automatisms that consolidate over time, thereby promoting a greater ability to read the game. Furthermore, recent research has confirmed that integrating technological tools such as interactive lights (Le Reactiva) can significantly stimulate these skills through high-frequency visual-motor exercises, thereby improving reaction time, visual accuracy, and hand-eye coordination (Ghasemi et al., 2023).

At the same time, collaboration is another key aspect of developing athletes in team sports. This is evident in the ability to communicate, support teammates and make decisions in sync with them. As a highly interdependent sport, football requires continuous adaptation to collective movements and constant attention to what is happening to the side and behind. Therefore, it is not surprising that peripheral vision also plays a key role in the relational sphere. Being able to grasp the position of teammates in real time improves the fluidity of play and the effectiveness of cooperative strategies (Travassos et al., 2017).

According to a recent systematic review, learning environments that combine perceptual stimuli with cooperative exercises are particularly effective in developing the tactical and social skills of young footballers (O'Connor et al., 2018). Using technology as a teaching tool also enables personalised training according to age and motor development level, promoting individual and team improvement (Rago et al., 2022).

Recent research has highlighted that specific perceptual-motor training can significantly enhance the speed and effectiveness with which players respond to environmental stimuli, thereby improving their performance on the field (Romaes et al., 2016; Schwab & Memmert, 2019).

Well-structured perceptual training can strengthen self-confidence, improve emotional management during play, and promote greater confidence in movements and decisions (O'Connor et al., 2018; Ghasemi et al., 2023).

In highly cooperative games such as football, peripheral vision enables players to read collective dynamics more accurately and align their movements more effectively with those of their teammates, thus increasing the effectiveness of shared actions (Travassos et al., 2017; Gonçalves et al., 2021).

Therefore, peripheral vision and collaboration are educational skills that are intertwined with the identity of the young athlete, not just technical ones. Integrating devices that stimulate perception and social interaction simultaneously into training programmes creates a rich, motivating learning environment that aligns with contemporary sports pedagogy trends.

This study aims to evaluate the effectiveness of an educational intervention designed to stimulate and develop the peripheral vision of young footballers aged 8–16 enrolled in a sports club in Naples. The study analyses three fundamental dimensions of athletic development: reactivity to visual stimuli, perceived self-efficacy, and the ability to collaborate in a game context. Specifically, the study:

- Examined improvements in reaction speed to peripheral visual stimuli, a crucial skill in high-intensity decision-making sports such as football.
- Assessed changes in perceptions of physical self-efficacy using the Physical Self-Efficacy Scale for Children (PSES).
- Analysed the evolution of peer collaboration using the Youth Sport Environment Questionnaire (YSEQ) as a measurement tool.

The proposed educational intervention integrated visual-motor exercises with Le Reactiva interactive smart lights, which provided dynamic and customisable visual stimuli. This multidimensional approach aimed to improve both personal and social skills of young athletes through a programme tailored to their developmental characteristics.

2. METHODS

2.1. Participants

Using a mixed-methods (quantitative-qualitative) design, this study examined a sample of 100 young footballers, aged between eight and 16, who were enrolled in a football school in Naples.

Participants were selected through intentional sampling, following strict inclusion and exclusion criteria, with the aim of ensuring the homogeneity of the group, the methodological quality of the study and the internal validity of the data collected (Thomas, Nelson & Silverman, 2019). The inclusion criteria adopted for admission to the study are as follows:

- Informed consent was signed by parents or legal guardians in line with the ethical guidelines for research involving minors.
- Voluntary participation by young athletes in accordance with the principles of self-determination and progressive empowerment, as set out in the guidelines for educational research in sport.
- Attendance at more than 50% of the scheduled training sessions during the educational intervention. This criterion has been adopted to ensure sufficient exposure to stimuli and methodological consistency (Rago et al., 2022).
- Minimum experience of at least two continuous years in football is required to ensure that participants have the technical and motor skills necessary for perception-motor exercises of intermediate complexity (Ford et al., 2017).

The main exclusion criteria were:

- Subjects with visual impairments that could affect their response to light stimuli, thereby compromising the reliability of the results, were excluded from participation.
- High myopia (>5 dioptres) that was not corrected by appropriate devices, as this can significantly reduce the quality of peripheral and central vision (Ghasemi et al., 2023).
- Ocular pathologies such as retinal detachment, severe strabismus or retinal degeneration were also excluded, as these have been reported in the literature as factors limiting spatial detection and visual discrimination;

To ensure a controlled experimental comparison, the sample was divided into two homogeneous groups: An experimental group (n = 50), who underwent a training cycle integrated with Le Reactiva smart lights, which are specifically designed to stimulate peripheral vision and visual-motor reactivity: A control group (n = 50) continued the traditional technical-tactical programme without the introduction of additional perceptual interventions.

The groups were formed based on criteria relating to age, football experience and average training frequency, in line with the experimental protocols recommended in the literature on youth training (Coutinho et al., 2016; Gonçalves et al., 2021). This approach minimised the risk of bias and

promoted comparability between groups, enabling the differential analysis of the intervention's impact. The entire selection and division process was overseen by the sports club's internal technical committee in collaboration with the project's scientific director. This process was conducted in full compliance with the ethical regulations governing research involving minors, as well as school and extracurricular physical activity (O'Connor et al., 2018).

2.2. Detection Tools: Quantitative and Qualitative Approach

To ensure a comprehensive and in-depth analysis of the effectiveness of the proposed educational intervention, the research adopted a mixed-methods approach, combining standardised quantitative tools with qualitative observations and narratives. This approach aligns with current trends in applied research in motor skills and pedagogy, where the integration of objective and subjective data is promoted to gain a comprehensive understanding of the phenomenon under study (Creswell & Plano Clark, 2017; Bailey et al., 2020). This approach enabled the capture of measurable changes in performance as well as the perceptual, motivational, and relational transformations experienced by young athletes during training.

2.2.1. Quantitative Tools

Peripheral visual reactivity test with Le Reactiva

To objectively measure the ability to respond to peripheral visual stimuli, a specific protocol based on Le Reactiva interactive lights was employed. The lights were positioned around the athlete in a variable manner and activated randomly, requiring a rapid motor response (e.g. touching, moving or jumping in a specific direction). The system automatically recorded reaction time, response speed, and the accuracy of execution. This tool has been shown to be highly sensitive in detecting perceptual-motor improvements, making it particularly suitable for subjects of developmental age (Ghasemi et al., 2023).

Physical Self-Efficacy Scale for Children (PSES)

To investigate the subjective dimension of physical self-efficacy, the PSES questionnaire, consisting of 16 items on a 5-point Likert scale, was administered. The scale explores two fundamental domains: confidence in motor skills (e.g. balance, agility and strength) and sense of body control (i.e. the ability to manage one's body in dynamic situations). The scale has been validated for the 8–16 age group and has demonstrated solid reliability and construct validity indicators. It is also widely used in international research on the development of self-efficacy in sporting contexts (Rigby et al., 2018; O'Connor et al., 2018).

Youth Sport Environment Questionnaire (YSEQ)

The YSEQ (Carron et al., 2002) was used to assess cooperative dynamics and the perceived relational climate within the team. This psychometric tool is designed to measure cohesion in youth sports contexts. The questionnaire is divided into subscales relating to social cohesion (the affective relationships between members) and task-oriented cohesion (the level of collaboration in achieving sporting goals). It was administered with the support of coaches to make the items more accessible and easier to understand for younger participants (Bruner et al., 2014).

2.2.2. Qualitative Tools

Systematic observation in game situations

During training and game sessions, systematic observations were conducted using a behavioural grid designed specifically for this study. The following indicators were observed: effective use of peripheral vision; situational anticipation skills; spontaneous collaborative interaction; and real-time decision-making. The sessions were recorded and analysed independently by two expert observers, and the data were subsequently compared to ensure inter-observer reliability (Anguera et al., 2017). This tool made it possible to detect emerging behaviours that would be difficult to capture through questionnaires alone.

Post-intervention semi-structured interviews

To enrich the quantitative data with subjective elements, semi-structured interviews were conducted with the young footballers from both groups. The questions focused on three main areas: their perception of improvement, motivation during the intervention, and collaboration with teammates. Conducted in a familiar and non-evaluative context, the interviews produced rich narrative and emotional data, providing fundamental insights into how young athletes experience motor and relational learning (Sparkes & Smith, 2014).

Coaches' logbooks

Finally, coaches from both groups completed weekly reflective logbooks, recording observations regarding active participation, motivation, group dynamics and technical and relational progress. These logbooks provided an invaluable educational perspective, which was essential for triangulating the data and enriching the final analysis with the adult mediator's viewpoint (Bailey et al., 2020). The qualitative data from these logs also highlighted the group's level of engagement with, and adaptation to, the innovative approach proposed.

2.3. Educational Intervention: Structure, Content and Differentiation by Age Group

The educational intervention consisted of three weekly sessions, each lasting 60 minutes, over a period of 12 weeks. It included two distinct training programmes: one for the experimental group involving visual-motor exercises using Le Reactiva interactive lights, and a traditional programme for the control group focusing on standard technical-tactical activities. The activities were adapted for two age groups (8–10 and 11–16 years) to respond to the developmental, cognitive, and physical needs of the participants, in line with the principles of differentiated motor development (Malina et al., 2004).

The experimental group undertook a progressive visual-motor programme designed to improve peripheral vision, responsiveness to environmental stimuli, and spatial awareness during play. Le Reactiva enabled dynamic, customisable exercises to be offered, with the intensity, distance and complexity of the stimuli modulated according to age and motor skills.

2.3.1. 8–10 y.o.

For young footballers aged 8–10, the programme focused on integrated perceptual and attentional skill development through play, using multisensory and exploratory exercises to encourage motivation and engagement. This approach aligns with the latest guidelines on motor and cognitive development in children, which emphasise the importance of varied and adaptive stimuli (Smith et al., 2019; Pereira et al., 2021). The main activities included:

- “Light tour” at stations: children rotated between circular stations where they had to quickly identify and reach coloured lights that were activated at random. This exercise aims to enhance peripheral perception, hand-eye coordination, and reaction speed — all of which are essential for developing visual-spatial and motor skills (Panchuk et al., 2015; Johnson et al., 2020).
- Motor courses with intermittent visual stimuli: within a motor course consisting of jumps, slaloms and rolls, intermittent light stimuli were inserted that required quick and precise responses. These exercises promote integration between the visual and motor systems, thereby improving selective attention and response readiness (Ryu et al., 2015; Broadbent et al., 2020; Li et al., 2022).
- "Pair reaction" with light and a partner: two children cooperated to respond to peripheral stimuli, stimulating non-verbal communication and shared coordination. These aspects are

crucial for developing social and tactical skills in team play (Memmert et al., 2009; Smeeton et al., 2022; Baker & Collins, 2017).

The playful approach respected the cognitive and neuromotor rhythms typical of this age group. Interactive lights were used to enhance attention processes and the ability to process complex visual stimuli during movement (Sigrist et al., 2013; Dell'Angelo et al., 2021).

2.3.2. 11–16 y.o.

For the 11–16 age group, the training was designed to simulate the real dynamics of the game. The exercises involved high cognitive and motor demands and were aimed at encouraging rapid decision-making in complex environments. Recent literature widely confirms the importance of visual-motor and tactical training in this age group, emphasising the key role of game-reading ability and visual reactivity (Roca et al., 2019; Travassos et al., 2017). The main activities included:

- Circuits with double visual stimuli: two lights were activated in sequence in the player's peripheral vision, requiring them to perform different motor actions (e.g. touch and sprint) in response to the colour and position of the stimuli. This exercise improves visual discrimination, cognitive flexibility, and motor planning (Williams et al., 2011; Ghasemi et al., 2023; Nakamoto & Mori, 2018).
- "Situational perception" exercises (3 vs 3): during mini-matches, lights were activated near free spaces or unmarked players. This trains peripheral attention and the ability to read and anticipate the tactical context in real time — essential skills in team sports (Travassos et al., 2017; Araújo & Davids, 2016; Lopes et al., 2020).
- Integrated stimulus technique: passing, unmarking and dribbling exercises conducted with light activations in unexpected areas of the field. For instance, a light behind a player could signal the arrival of an unmarked teammate, thereby stimulating the effective use of peripheral vision and encouraging quick and informed decision-making (Schwab & Memmert, 2019; Vignais et al., 2015; Müller et al., 2021).

Using Le Reactiva lights enabled the stimuli to be dynamically customised based on the participants' attention and motor skills. This optimised the synergy between visual perception, motor response and tactical choice. These are all essential elements in cognitively demanding sports such as football (Roca & Williams, 2016; Furley & Memmert, 2018).

The control group continued with a traditional technical-tactical programme in accordance with standard football school protocols, without integrating technological visual-motor stimuli. This

was done to maintain a balanced workload and ensure parity with the experimental group in terms of training volume and intensity while prioritising the development of classic technical and tactical skills, which are fundamental to football development.

2.3.3. 8–10 y.o.

For this age group, the intervention involved activities designed to develop basic motor skills and introduce children to the key elements of play. This approach was playful and exploratory, in line with guidelines on sensorimotor and socio-emotional development in young children (Ford et al., 2017; Lopes et al., 2019). The main activities included:

- Ball control games and obstacle courses involving controlling the ball in motion, dribbling in marked areas, wall passes and shooting at a goal. These drills promote eye-foot coordination, timing, and personal space management in dynamic contexts (Roca et al., 2018; Li et al., 2020).
- 3 vs 3 or 5 vs 5 small-sided games aimed at developing basic tactical awareness, spatial orientation and teamwork. These games allow for more contact with the ball and quick decision-making (Gonçalves et al., 2018).
- Group activities: exercises aimed at promoting respect for the rules, turn-taking and communication on the pitch, which are fundamental aspects of social inclusion and cooperative learning (Martínez-López et al., 2019).

This approach complied with the principles of motor and cognitive development typical of the 8–10 age group, for whom exploration and play remain crucial for motor learning and motivation (Barnett et al., 2020).

2.3.4. 11–16 y.o.

For boys approaching or in the midst of puberty (aged 11–16), technical and tactical training focused on perfecting specific skills and developing an advanced understanding of game dynamics. This approach is in line with developmental and methodological models for high-level youth football (Ford & Williams, 2017; González-Víllora et al., 2019). The main activities included:

- Training on offensive and defensive schemes, comprising structured sessions for learning and repeating tactical models such as zone pressing, defensive-offensive transitions, and space coverage. This promotes an understanding of the individual's role within the game system (Silva et al., 2018; Silva et al., 2020).

- Advanced technical drills: specific exercises focused on passing the ball while moving, counterattacks, and possession management; training in executing techniques under pressure; and developing decision-making skills in simulated real-game conditions (Santos et al., 2022).
- Themed 7 vs 7 or 9 vs 9 matches were also included, which took place on a medium-sized pitch. These matches had defined technical and tactical objectives, such as quick transitions, use of the width of the pitch and space management. This allowed players to integrate their individual and collective skills in small competitive contexts (Sarmiento et al., 2018; Ziv & Lidor, 2019).

This structure stimulated tactical analysis and technical execution skills, which are consistent with the developmental needs of adolescents engaged in sports training. This approach is in line with periodisation and mental load models that are appropriate for their level of maturity (Lloyd & Oliver, 2012; Vaeyens et al., 2019). The methodological framework ensured internal consistency, personalisation of the intervention, and adaptation to the participants' real needs, thereby reinforcing the effectiveness of the training experience proposed.

2.4. Statistical Analyses

The quantitative data were analysed using descriptive and inferential procedures, with the aim of examining the trend of the variables over time and comparing the effectiveness of the two training programmes. For each variable considered — reaction time to peripheral stimuli (TR), physical self-efficacy (PSES) and team cohesion (YSEQ in the “task” and “social” components) — means, standard deviations and indicators of change were initially calculated, including percentage changes, in order to facilitate an understanding of the practical impact of the training.

To evaluate the effect of the interactive light training programme compared to traditional training and analyse the evolution of the measures over the 12 weeks, a repeated measures ANOVA with a 2×2 design was conducted, considering the Survey as an within-subject factor and the Group (experimental vs control) as a between-subject factor. This analysis was applied separately to each dependent variable.

In order to explore possible differences related to development, an analysis of the Group \times Age Group (8–10 vs. 11–16) interaction was also included, with the aim of verifying whether the effect of the intervention varied according to the age of the participants.

The threshold for statistical significance was set at $p < .05$. Where appropriate, the interpretation of the results was also supported by indicators of practical relevance, such as the extent of the changes observed and the average differences between experimental conditions, in line with methodological recommendations for applied research in the field of sport.

3. RESULTS

3.1. Quantitative Data Results

Table 1 shows the baseline characteristics of the study sample and confirms that the experimental and control groups were well balanced at the start of the study.

Table 1. Sample characteristics

Variable	Total (N = 100)	Experimental Group (n = 50)	Control Group (n = 50)
Age (years), mean \pm SD	11.8 \pm 2.6	11.7 \pm 2.6	11.9 \pm 2.5
Age group, n (%)			
• 8–10 years	50 (50%)	25 (50%)	25 (50%)
• 11–16 years	50 (50%)	25 (50%)	25 (50%)
Sex, n (%)			
• Males	92 (92%)	46 (92%)	46 (92%)
• Females	8 (8%)	4 (8%)	4 (8%)
Years of soccer practice, mean \pm SD	4.1 \pm 1.6	4.1 \pm 1.6	4.0 \pm 1.5
Experience \geq 2 years, n (%)	100 (100%)	50 (100%)	50 (100%)
Training sessions per week, mean \pm SD	3.0 \pm 0.3	3.0 \pm 0.3	3.0 \pm 0.3
Program adherence (% of sessions), mean \pm SD	86 \pm 9	87 \pm 8	85 \pm 9
Adherence > 50% of sessions, n (%)	100 (100%)	50 (100%)	50 (100%)
Visual correction (glasses/contact lenses), n (%)	10 (10%)	5 (10%)	5 (10%)

Table 1 shows that the experimental and control groups were highly comparable at baseline. Participants had a similar mean age (\approx 11.8 years), equal age distribution, and identical sex distribution (92% male, 8% female). Both groups also showed similar football experience (about 4 years), equal training frequency (3 sessions/week), and full minimum experience (\geq 2 years in all participants). Program adherence was high and comparable between groups (86–87%), and only 10% of participants in each group used visual correction. Overall, the two groups were well balanced before the intervention. Table 2 shows the effects of the intervention on peripheral visual reaction time, while table 3 presents the results by age group.

Table 2. Peripheral Visual Reaction Time (RT, ms)

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Δ %	p (Group × Time)
Total EG (n = 50)	520 ± 65	430 ± 58	-17.3%	< .001
Total CG (n = 50)	515 ± 68	495 ± 66	-3.9%	.18

Table 3. Age-group analysis

Age group	EG Pre	EG Post	Δ %	CG Pre	CG Post	Δ %
8–10 years	545 ± 60	480 ± 55	-12.0%	540 ± 62	525 ± 60	-2.8%
11–16 years	495 ± 63	405 ± 52	-18.2%	490 ± 66	465 ± 64	-5.1%

Quantitative comparisons were made between the experimental group (GS) and the control group (GC), and between the two age groups (8–10 years and 11–16 years). These comparisons showed statistically and clinically significant differences, in line with recent literature (Rossi & Di Pietro, 2021).

On average, the GS showed an improvement in reaction time (RT) to peripheral light stimuli of between 15% and 20%, whereas the GC showed marginal increases of less than 5%. In the control group, the variations observed ($\leq 5\%$) did not reach statistical significance ($p = .18$) and are therefore attributable to non-specific effects or natural learning. These results confirm previous observations on the effectiveness of visuomotor training using dynamic light stimulation (Müller et al., 2023), where only those undergoing structured programmes experienced a significant reduction in response times. In particular, the improvement was more pronounced in the 11–16 age group (~18%), highlighting greater perceptual and reactive plasticity in pre-adolescence (Fang & Lee, 2019). However, even in the 8–10 age group, the average improvement was around 12%, with variations between individuals attributable to differences in cognitive and visual-attentional development (Gentile et al., 2017). Table 4 shows the effects of the intervention on physical self-efficacy (PSES scores) while table 5 presents the age-group analysis for physical self-efficacy.

Table 4. Physical Self-Efficacy Scale (PSES, 1–5)

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Δ	p (Group × Time)
Total EG	3.4 ± 0.5	4.0 ± 0.4	+0.6	< .01
Total CG	3.5 ± 0.5	3.6 ± 0.5	+0.1	.22

Table 5. Age-group analysis

Age group	EG Pre	EG Post	Δ	CG Pre	CG Post	Δ
8–10 years	3.3 ± 0.4	3.8 ± 0.4	+0.5	3.4 ± 0.5	3.5 ± 0.5	+0.1
11–16 years	3.5 ± 0.5	4.2 ± 0.4	+0.7	3.6 ± 0.5	3.7 ± 0.5	+0.1

The average PSES score increased by approximately +0.6 points on a Likert scale of 1–5 in the GS, compared to an increase of just +0.1 in the CG. This improvement reflects a strengthening of perceived physical self-efficacy, which is a well-documented effect of training that integrates motor and cognitive stimuli (Santangelo et al., 2022; Meijer & Tomasini, 2016). The 11–16 age group recorded a slightly higher increase of +0.7, suggesting that adolescents and pre-adolescents may be more sensitive than younger children to the psychological aspects of training that focus on body control and motor awareness (Zhou et al., 2021). Table 6 shows the effects of the intervention on task cohesion (YSEQ), while Table 7 presents the effects on social cohesion (YSEQ).

Table 6. Youth Sport Environment Questionnaire (YSEQ) – task cohesion

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Δ	<i>p</i>
Total EG	3.6 ± 0.4	4.1 ± 0.4	+0.5	< .01
Total CG	3.7 ± 0.5	3.8 ± 0.5	+0.1	.30

Table 7. Youth Sport Environment Questionnaire (YSEQ) – social cohesion

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Δ	<i>p</i>
Total EG	3.8 ± 0.4	4.2 ± 0.4	+0.4	< .01
Total CG	3.9 ± 0.4	4.0 ± 0.4	+0.1	.27

Analysis of data on team cohesion, as measured by the YSEQ, revealed notable enhancements in task cohesion (+0.5) and social cohesion (+0.4) within the GS. In contrast, changes within the CG were negligible (+0.1–0.2). This confirms that greater spatial awareness and more effective peripheral vision can promote non-verbal communication, synchronisation, and interaction between peers (Di Giacomo & Alberti, 2019). Once again, subjects aged 11–16 showed slight advantages in terms of progress while maintaining a positive trend even among the youngest subjects. Table 8 presents the statistical analysis of the intervention effects over

time, comparing the experimental and control groups across all measured outcomes (reaction time, physical self-efficacy, task cohesion, and social cohesion).

Table 8. Effects of the intervention on performance, psychological, and cohesion outcomes: repeated-measures ANOVA results

Variable	Group Effect	Time Effect	Group × Time Interaction	Group × Age Interaction
RT	p < .001	p < .001	p < .01	n.s.
PSES	p < .01	p < .01	p < .05	n.s.
YSEQ – Task Cohesion	p < .01	p < .01	p < .05	n.s.
YSEQ – Social Cohesion	p < .01	p < .01	p < .05	n.s.

Note. n.s. = not significant ($p > .05$)

Analysis of repeated measures ANOVA confirmed the statistical significance of the differences between GS and GC for all three analysed variables: peripheral visual reactivity, physical self-efficacy, and team cohesion ($p < 0.01$). The main effect of the intervention was robust and significant. However, the interaction between group and age group did not reach statistical significance ($p > 0.05$). This suggests that the intervention was generally effective in both age groups (Martins et al., 2016; Vetrano et al., 2025). This implies that the Le Reactiva smart lighting protocol can activate cross-cutting mechanisms of perceptual and relational learning regardless of age.

3.2. Qualitative Data Results

Analysis of the semi-structured interviews revealed significant differences between the experimental and control groups in the three investigated areas. Students in the experimental group reported a more pronounced perception of their own improvement, describing progress primarily in terms of decision-making speed, spatial awareness, and the ability to 'see ahead' in the game. Visuo-motor technologies, such as the Le Reactiva lights, were frequently mentioned as 'fun but challenging' tools that 'help you concentrate more'.

Qualitative data collected through interviews, systematic observations and reflective diaries of coaches were analysed using thematic analysis, a particularly suitable approach for exploring subjective perceptions and emerging meanings in educational and sporting contexts (Nowell et al., 2017; Braun et al., 2019). Following the six steps suggested by Braun and Clarke (2016), the transcripts were manually coded by two researchers independently: familiarisation with the data; generation of initial codes; search for themes; review of themes; definition and naming; and report writing. The analysis was further strengthened by triangulating the data from different sources (players, coaches and observers) to increase reliability and the depth of interpretation (Smith & Sparkes, 2020; Santos et al., 2022).

In contrast, participants in the control group reported more traditional improvements, mainly related to technical aspects. Comments highlighted learning that was 'more similar to previous years', albeit still positive.

In terms of motivation, the experimental group generally displayed higher levels, expressing enthusiasm for the novelty of the exercises, the variety of stimuli, and the playful technological dimension of the activities.

Several students emphasised that 'every training session was different' and 'it was never boring'. In contrast, motivation in the control group was more heterogeneous: some appreciated the continuity and clarity of the technical objectives, while others perceived a certain repetitiveness in the activities and experienced less emotional involvement, particularly among those aged 11–16. Finally, with regard to collaborative experiences, participants in the experimental group demonstrated a strong sense of cohesion and cooperation. This was partly due to the interactive nature of the exercises, which often required shared responses to stimuli. Young people reported that they 'communicated more without talking', 'developed a different kind of understanding' and 'felt more like a team'. In the control group, collaboration was also perceived as an integral part of the game, albeit in a less intense and reflective manner. Relational dynamics remained stable, though they were rarely described as transformative or particularly meaningful.

The weekly diaries completed by the coaches offered an in-depth, contextualised view of the intervention, emphasising positive developments in perception, motor skills, relationships, motivation, and metacognition.

Over the last four weeks, the athletes in the experimental group demonstrated greater autonomy in interpreting and managing light stimuli, requiring significantly fewer instructions from the coaches. They began to anticipate when the lights would come on, recognise recurring patterns, and plan their movements in advance. This indicates that they had effectively internalised the task and strengthened their anticipatory processes.

Meanwhile, despite following a traditional and well-structured technical-tactical programme, the athletes in the control group did not demonstrate comparable signs of autonomy in interpreting the situation or reacting to unplanned environmental stimuli. The coaches noted that the children in the control group remained dependent on external cues, focusing mainly on the ball or their direct opponent. This gave them a narrower, more reactive view of the game than the proactive, broader view developed by the experimental group.

Another significant finding from the diaries concerns peer collaboration. The coaches in the experimental group observed a marked improvement in group dynamics; the children were more willing to cooperate, even in exercises not directly related to the use of lights. They shared strategies and gave each other suggestions. This behaviour suggests a possible positive 'cross-cutting' effect of the intervention, which can act on relational aspects and the co-construction of the game, thereby promoting a more inclusive, participatory, and self-regulated climate.

In the control group, on the other hand, the level of collaboration remained stable and was more closely linked to the team's previous habits. While maintaining a good level of discipline and participation, the children in this group tended to interact with each other in a more functional than strategic way. They showed less initiative in proposing alternative plays or adapting to changing contexts.

Finally, the coaches also reported differences in motivation. While participation in activities was seen as more routine in the control group, the experimental group showed stronger emotional involvement, particularly thanks to the novelty of the Le Reactiva lights. These were perceived as a personal and collective challenge. This fostered a sense of shared self-efficacy, generating enthusiasm and a sense of belonging within the group.

4. DISCUSSION

The results of this study confirm the effectiveness of visual-motor intervention based on the use of dynamic lights (Le Reactiva) in promoting significant improvements in both perceptual-motor and psychosocial aspects in young athletes. In line with recent studies (Müller et al., 2023), the experimental group showed substantial reductions in reaction times to peripheral stimuli, indicating an enhancement of distributed attention and anticipatory mechanisms. These results are particularly evident in the 11–16 age group, supporting the greater neurocognitive plasticity observed during pre-adolescence and adolescence (Fang & Lee, 2019). At the same time, the increase in perceived physical self-efficacy in the experimental group reflects recent motivational models, which suggest that the perception of challenge, variety and control in physical activity is a key factor in the growth of self-efficacy (Santangelo et al., 2022; Meijer & Tomasini, 2016). The integration of cognitive and sensory components, as in the protocol adopted, contributes to stimulating meaningful and self-regulated learning (Zhou et al., 2021). The improvement in team cohesion, measured using quantitative and qualitative tools, suggests that interaction mediated by shared visual stimuli can enhance implicit communication and synchronisation between peers (Di Giacomo & Alberti, 2019).

Furthermore, coaches' diaries highlight a progressive evolution in decision-making autonomy and peer cooperation, aspects considered central to contemporary pedagogical models of collaborative sports learning (Rossi & Di Pietro, 2021; Vetrano et al., 2025). The fact that the interaction between the group and age group was not statistically significant ($p > 0.05$) confirms the generalisability of the intervention, which is capable of activating cross-cutting mechanisms of visual-motor and emotional learning, regardless of age (Martins et al., 2016). In summary, the use of interactive technologies such as *Le Reactiva* is an effective educational and training resource, capable of simultaneously improving sports performance, intrinsic motivation and the quality of relationships in groups of young athletes.

The intervention was particularly effective with the 11–16 age group, where greater neurocognitive plasticity and the maturation of executive functions facilitate the assimilation of complex perceptual strategies (Fang & Lee, 2019). Nevertheless, even in the early stages of motor development, participants aged 8–10 showed significant progress, validating the approach in line with the principles of learning window theory (Barnett et al., 2020; Pereira et al., 2021).

Coaches' observations and athletes' testimonials also highlight a substantial impact on metacognition and motivation, with increased decision-making autonomy, anticipation skills, and emotional engagement. These elements are central to contemporary educational models in sport, which promote the development of athletes as reflective, self-determined, and socially competent individuals (Bailey et al., 2020; Santangelo et al., 2022). When integrated effectively and calibrated for age and developmental level, technology can be an effective teaching tool and a means of facilitating the development of a sporting identity in young people (Meijer & Tomasini, 2016; Helsen et al., 2021).

In particular, collaboration is enhanced by the shared use of peripheral visual stimuli and joint execution of reactive tasks. This translates into greater social cohesion and tactical synchronisation, which are fundamental to youth football (Di Giacomo & Alberti, 2019). These group dynamics, which can also be observed outside activities involving lights, suggest a possible transfer of visual-motor experience to broader cooperative contexts, as hypothesised in ecological models of situated learning (O'Connor et al., 2018).

The results obtained also reinforce the idea that sport can be a powerful vehicle for inclusion, provided that the methodologies adopted are designed to enhance cooperation, participation and diversity of skills. As Tafuri et al. (2025) suggest, 'school and extracurricular sport can become a

privileged space for inclusive education if based on flexible structures, interchangeable roles, and an ethic of collaboration' (p. 1153). Thanks to the integration of Le Reactiva lights, the protocol presented here has made it possible to create such conditions.

In line with the Baskin project model, the present study also emphasised the pivotal role of group dynamics in fostering the engagement and personal development of each athlete. By stimulating continuous implicit communication and shared attention, the visual-motor activities contributed to creating an 'inclusive climate based on mutual respect and responsibility' (Tafari et al., 2025, p. 1157), demonstrating a potential transformative impact that extends beyond the playing field.

5. CONCLUSIONS

This study confirms the effectiveness of integrating interactive visual-motor devices, such as Le Reactiva lights, into training programmes for young footballers. This contributes significantly to the development of motor, cognitive, and relational skills. Quantitative and qualitative data demonstrate that these tools significantly enhance responsiveness to peripheral stimuli, self-efficacy perception, and peer collaboration. This corroborates previous literature highlighting the positive impact of dynamic visual stimulation on selective attention, decision-making speed, and spatial-temporal coordination (Ghasemi et al., 2023; Müller et al., 2023).

In light of this evidence, it is important to emphasise the need for educational interventions in youth sport that not only enhance performance, but also promote personal and social development.

The structured and systematic inclusion of interactive technologies in youth training programmes is recommended, not only as tools to improve athletic performance, but also as multifunctional educational mediators capable of acting simultaneously on the body, mind and social relationships. Future research should investigate the long-term effects of such interventions and their integration into technical-tactical periodisation models for young people (Ford & Williams, 2017; Vetrano et al., 2025), taking an interdisciplinary approach to developing young athletes.

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AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

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