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Field Position- and Training Age-Related Differences in Motor-Cognitive Abilities of 10–17-Year-Old Soccer Players

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Abstract

In team sports such as soccer, players must rapidly and accurately process dynamic visual scenes based on the real-time movements and positioning of teammates and opponents. This study aimed to investigate differences in brain processing speed, cognitive agility, and lower-limb reactive agility among youth soccer players aged 10–17 years, considering both field position and level of playing experience. A total of 142 male players (mean age 13.27±2.35 years) were assessed and categorized according to their training age and field position. Brain processing speed and cognitive agility were measured using the Witty SEM system with the BrainHQ Hawk Eye and BrainHQ Agility tests, while lower-limb reactive agility was evaluated via the Fitro Agility Check. Players with 7–9 years of training experience achieved significantly faster brain speed reaction times (BSRT; $p=0.013$, $\eta p^2=0.076$) and lower complex disjunctive reaction times (CDR; $p<0.001$, $\eta p^2=0.340$) compared with players with 1–3 years of experience. Large training-age effects were also found in all agility directions ($\eta p^2=0.277–0.385$). These findings demonstrate that greater sport experience is strongly associated with enhanced perceptual-cognitive and motor-reactive efficiency in youth soccer.

Keywords: *brain speed quality, cognitive agility, lower-limb reactive agility, training age, field position, soccer*

Introduction

Recent studies consistently highlight the strong interconnection between cognitive and motor functions in the context of youth sports performance. Cognitive domains such as attention, working memory, and executive control are closely tied to sport-specific skills including dribbling, ball control, and reaction speed (Scharfen & Memmert, 2019; Trecroci et al., 2021). Evidence indicates that athletes who exhibit higher proficiency in these cognitive areas tend to achieve superior results in tasks requiring rapid motor execution. Interventions that combine physical and cognitive demands—particularly dual-task cognitive-motor training—have been shown to improve both domains concurrently, enhancing anticipatory decision-making under pressure and refining athletes' ability to adapt their actions to rapidly changing game environments (Friebe et al., 2024; Lucia et al., 2024).

Such approaches are particularly relevant in soccer, where the constant flow of play demands simultaneous processing of sensory information and rapid motor responses. Decision-making in soccer relies heavily on the integration of perceptual input, memory recall, and accumulated tactical knowledge. Players must rapidly interpret visual cues such as the relative positions of teammates and opponents, available space, and movement trajectories to anticipate game developments and select appropriate motor actions (Habekost et al., 2024; Rodrigues et al., 2022). As experience increases, these processes become more automated and parallel in nature, allowing players to recognize familiar patterns and retrieve effective motor strategies with greater speed and accuracy (Ramsey et al., 2024). This shift from serial to parallel processing represents a hallmark of expertise in soccer and is strongly influenced by both the quality and quantity of training.

Training formats such as small-sided games and game-based dual-task exercises have been found to strengthen attention, situational awareness, and action selection, all while exposing players to match-like time constraints and unpredictability (Machado et al., 2024). Perceptual-cognitive skills—including decision-making speed, anticipation, and visual reaction time—are also fundamental determinants of agility and reactive movement performance in soccer. These skills enable players to detect, interpret, and respond to game-relevant stimuli in a fraction of a second, which is critical during dynamic, high-intensity situations (Demir & Kiyici, 2023; Horníková et al., 2024). In adolescent athletes, reactive agility has been shown to be significantly influenced by cognitive processing efficiency, particularly in scenarios that require rapid directional changes in response to unpredictable stimuli. Integrative training methods, in which sprinting, change-of-direction, and decision-making tasks are combined, have been demonstrated to yield improvements in both the physical and cognitive determinants of agility (Friebe et al., 2024). These findings support the use of multifactorial training programs that simultaneously target perceptual-cognitive and motor capacities in youth soccer development.

Training experience and sport-specific age emerge as key determinants of cognitive-motor efficiency. Players with greater exposure to structured soccer training typically show faster reaction times, superior attentional control, and more accurate decision-making under visually complex conditions (Klatt et al., 2021). Long-term engagement in sport appears to accelerate the development of neural pathways involved in rapid information processing and motor execution. Age-related improvements in agility, decision accuracy, and processing speed reflect the combined effects of biological maturation and accumulated sport-specific practice (Andrašić et al., 2021). Evidence suggests that implementing small-sided games and perceptual-cognitive drills at an early age may foster these developmental gains, particularly in enhancing players' ability to perform under cognitive and physical load (Machado et al., 2024).

Taken together, the literature demonstrates that both sport-specific experience and age contribute to improvements in perceptual-cognitive and motor skills in soccer. Experienced players generally display more efficient visual processing, quicker reaction times, and better tactical decision-making under pressure, reflecting the integration of accumulated playing knowledge with refined attentional control (Klatt et al., 2021). These developmental and experiential trends justify systematic comparisons of brain speed, disjunctive reaction time, and directional agility across different levels of training age and playing positions. The present study extends previous research by examining two major developmental determinants, training age and field position, within a single design. Earlier studies focused on these factors separately, while our approach provides an integrated view of how motor-cognitive abilities evolve across both. Identifying interactions between experience and positional demands offers new insights into evidence-based and position-specific training in youth soccer.

Materials and methods

Participants and design

This study was conducted as a four-group, two-factor, non-randomized cross-sectional design. A total of 142 male soccer players aged 10 to 17 years (mean age =13.27±2.35 years) participated in the research. Participants were categorized based on two independent grouping factors: training experience (training age) and field position. Training age was defined as the total number of completed years of organized soccer participation under qualified coaching supervision. Players were divided into four training-age groups TA1–3 years (n=25, M=10.7±1.2), TA4–6 years (n=48, M=11.8±0.8), TA7–9 years (n=49, M=14.6±0.8), and TA10–13 years (n=20, M=16.7±0.9) based on total years of experience. All participants competed in the same official youth categories according to their chronological age, which minimized biological-maturity differences across groups. Field position categories included defenders (n=57, M=13.1±0.5), strikers (n=43, M=13.2±2.3), midfielders (n=30, M=13.2±2.4), and goalkeepers (n=12, M=14.5±2.2).

Procedures

Testing took place during the competitive season, when all players were actively involved in structured training 3 to 4 times per week and one competitive match each weekend, resulting in a total weekly training volume of approximately 6 to 8 hours. Motor-cognitive performance was assessed using the Witty SEM diagnostic system (Andrašić et al., 2021; Vasile et al., 2024). Cognitive agility was measured by the BrainHQ Agility Test, in which the participant's task was to respond as quickly as possible to a green lowercase letter "a" appearing randomly among eight semaphores, while ignoring distractors composed of various letters and numbers displayed in other colors. Brain speed was measured using the BrainHQ Hawk Eye Test (also referred to as the Peripheral Vision Test), which challenges visual precision by requiring participants to locate bird-shaped symbols appearing for a brief moment in their peripheral field of vision. The test outputs included mean reaction time (brain speed reaction time – BSRT), number of correct responses (brain speed hits – BSH), and number of errors (brain speed errors – BSE). The brain speed quality index (BSQ) was calculated as the ratio of BSRT to BSH, representing processing efficiency. In both cognitive tests, participants responded to 15 visual stimuli presented randomly across the eight semaphores. Reactive agility of the lower limbs was evaluated using the Fitro Agility Check (Horická & Šimonek, 2021; Zemková & Hamar, 2013). This test involved 16 randomly generated visual stimuli—blue circles appearing on a screen in four possible directions (front, rear, left, right). Players responded by stepping on pressure-sensitive mats positioned at the corners of a 40 cm square. All testing procedures followed the official Witty SEM user protocol provided by Microgate (Witty User Manual, 2019). Measurements were performed on the same day and in the same indoor facility to eliminate environmental variation. The number, spatial arrangement, and mounting of sensors were configured exactly according to the manual. Identical calibration and timing protocols were used for all participants. Regarding familiarization, all participants received a standardized verbal explanation and live demonstration of each task. No separate practice trials were performed, as this ensured understanding without introducing learning effects. The cognitive and motor-cognitive tests were performed in a fixed sequence: first the BrainHQ Agility

Test, followed by the BrainHQ Hawk Eye Test, and finally the Fitro Agility Check. Both diagnostic systems have demonstrated high reliability and validity in adolescent populations (Andrašić et al., 2021; Zemková & Hamar, 2013).

Statistics

The mean of the four fastest responses in each direction was used for analysis. A one-way ANOVA (1×4; one factor with four levels) was employed to examine the effect of the grouping factor (training age or field position) on the measured motor-cognitive variables. Because the assumption of normality was violated (Shapiro–Wilk test; non-published results), rank transformation of the raw scores was applied prior to analysis. Homogeneity of variances was verified using Levene's test. Post hoc multiple comparisons were conducted using the least significant difference (LSD) test, selected due to the presence of statistically significant main effects and the exploratory nature of the study. Although LSD does not apply correction for multiple comparisons, it allows for greater sensitivity in detecting meaningful group differences. Effect sizes for ANOVA were calculated using eta squared (η^2) and interpreted as follows: <0.010 = no effect; 0.010–0.059 = small; 0.060–0.139 = medium; ≥0.140 = large. For post hoc pairwise comparisons, Cohen's d was calculated and interpreted as: 0.20–0.49 = small; 0.50–0.79 = medium; ≥0.80 = large. Statistical significance was set at α=0.05. All analyses were performed using Statistica software, version 13.5 (TIBCO Software Inc., Palo Alto, CA, USA).

Results

Field position did not show statistically significant effects (p>0.05), though small-to-moderate tendencies ($\eta p^2 \approx 0.05$) were observed: midfielders were fastest in BSRT, goalkeepers made the fewest BSE, and defenders had slightly higher BSQ. These patterns suggest positional tendencies rather than true group differences (Table 1).

Table 1. Results of descriptive characteristics of brain speed, disjunctive reactivity, and lower limb reaction speed of soccer players – field position view (presented as mean±SEM [95% CI])

Field post	Goalkeeper (n=12)	Defender (n=57)	Midfielder (n=30)	Striker (n=43)
BSRT (s)	0.442±0.095 [0.234-0.651]	0.555±0.032 [0.490-0.619]	0.554±0.035 [0.483-0.626]	0.516±0.038 [0.439-0.593]
BSE (n)	2.667 ± 0.284 [2.041-3.292]	3.122±0.100 [2.922-3.323]	3.167±0.108 [2.946-3.388]	2.927±0.123 [2.678-3.175]
BSQ (BSRT/BSH)	0.038±0.010 [0.016-0.060]	0.048±0.003 [0.042-0.055]	0.048±0.003 [0.041-0.055]	0.044±0.004 [0.037-0.052]
CDR (s)	23.490±1.228 [20.788-26.192]	27.510±0.885 [25.737-29.281]	26.401±1.263 [23.816-28.986]	29.503±1.641 [26.191-32.815]
Right (ms)	690.05±26.863 [630.92-749.17]	724.13±11.48 [701.12-747.13]	731.27±18.10 [694.18-768.35]	752.81±17.385 [717.7-787.92]
Left (ms)	730.54±39.550 [643.49-817.59]	720.681±11.903 [696.84-744.53]	716.34±19.626 [676.13-756.54]	741.13±16.636 [707.53-774.73]
Front (ms)	710.32±33.389 [636.83-783.81]	740.368±13.146 [714.03-766.70]	727.43±20.055 [686.35-768.51]	762.94±19.787 [722.98-802.91]
Rear (ms)	707.44±32.951 [634.91-779.96]	704.740±11.00 [682.69-726.79]	721.10±18.868 [682.44-759.74]	733.22±14.187 [704.57-761.87]

Note. SEM – standard error of mean; 95% CI – 95% confidence interval; bolded values in agility test directions (Right, Left, Front, Rear) indicate the fastest mean reaction time (i.e., lowest value) per direction across playing positions; BSRT = Brain Speed Reaction Time (s); BSE = Brain Speed Errors (number of incorrect responses); BSH = Brain Speed Hits (number of correct responses); BSQ = Brain Speed Quality (BSRT divided by BSH); CDR = Complex Disjunctive Reaction Time (s); Right, Left, Front, Rear = movement directions in the Fitro Agility Test (ms).

Descriptive and inferential statistics revealed significant training age-related differences in all cognitive-motor and agility variables (Table 2). Training age had a significant effect on all key performance indicators: BSRT ($F(3,138)=3.71$, p=0.013, $\eta p^2=0.076$), BSE (F=4.68, p=0.004, $\eta p^2=0.094$), BSQ (F=4.04, p=0.009, $\eta p^2=0.082$), and CDR (F=23.71, p<0.001, $\eta p^2=0.34$). Directional agility also demonstrated robust effects across all movement directions ($\eta p^2=0.20$–0.39, all p<0.001), confirming substantial developmental gains in reaction speed and coordination. Post hoc tests showed that players with 7–9 years of experience significantly outperformed those with 1–3 years across all agility directions (Cohen's d=1.3–1.9, large effects) and achieved superior cognitive efficiency in BSQ (d=1.6). Within-group contrasts revealed slower rear-direction responses in the youngest players (p<0.05), suggesting early developmental asymmetries (Table 3; Figure 2).

Table 2. Results of descriptive characteristics of brain speed, disjunctive reactivity, and lower limb reaction speed of soccer players – training age view (presented as mean±SEM [95% CI])

Training age (TA)	$TA_{1\text{-}3years}$ (n=25)	$TA_{4\text{-}6\ years}$ (n=48)	$TA_{7\text{-}9\ years}$ (n=49)	$TA_{10\text{-}13\ years}$ (n=20)
BSRT (s)	0.645±0.056 [0.530-0.760]	0.558±0.034 [0.490-0.626]	0.467±0.032 [0.403-0.530]	0.507±0.051 [0.400-0.614]
BSE (n)	3.417±0.146 [3.114-3.720]	3.149±0.101 [2.951–3.347]	2.776±0.110 [2.554-2.997]	2.950±0.170 [2.595-3.305]
BSQ (BSRT/BSH)	0.057±0.006 [0.045-0.069]	0.048±0.003 [0.042-0.055]	0.039±0.003 [0.033-0.046]	0.043±0.005 [0.033-0.054]
CDR (s)	34.333±1.629 [30.972-37.695]	29.943±1.263 [27.402-32.484]	23.727±0.702 [22.316-25.139]	22.615±0.992 [20.539-24.691]
Right (ms)	827.958±21.086 [784.44-871.48]	758.07±10.797 [736.33-779.82]	677.10±10.83 [655.33-698.88]	681.60±16.38 [647.32-715.89]
Left (ms)	813.31±18.574 [774.97-851.64]	752.27±10.687 [730.74-773.79]	685.37±14.932 [655.34-715.39]	661.34±16.83 [626.12-696.55]
Front (ms)	857.13±20.081 [815.68-898.57]	774.31±12.913 [748.30-800.32]	684.79±12.971 [658.71-710.87]	663.15*±15.34 [631.03-695.26]
Rear (ms)	789.23*±18.926 [750.17-828.29]	735.57±10.817 [713.78-757.35]	677.03±12.508 [651.89-702.19]	681.24±17.16 [645.33-717.16]

Note. SEM – standard error of mean; 95% CI – 95% confidence interval; bolded values in agility test directions (Right, Left, Front, Rear) indicate the fastest mean reaction time (i.e., lowest value) per direction across training age groups; BSRT = Brain Speed Reaction Time (s); BSE = Brain Speed Errors (number of incorrect responses); BSH = Brain Speed Hits (number of correct responses); BSQ = Brain Speed Quality (BSRT divided by BSH); CDR = Complex Disjunctive Reaction Time (s); Right, Left, Front, Rear = movement directions in the Fitro Agility Test (ms).

Table 3. Results of one-way ANOVA assessing the effects of playing position and training age on motor-cognitive and agility variables

Test	Factor	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared / ηp²
BSRT	Training age	15768.02	3	5256.01	3.71	0.013*	0.076†
	Field post	9834.62	3	3278.21	2.24	0.086	0.047
BSE	Training age	18061.22	3	6020.41	4.68	0.004*	0.094†
	Field post	7397.26	3	2465.75	1.81	0.149	0.038
BSQ	Training age	17076.94	3	5692.31	4.04	0.009*	0.082†
	Field post	9956.48	3	3318.83	2.27	0.083	0.048
CDR	Training age	81147.55	3	27049.18	23.71	0.0001*	0.340‡
	Field post	7424.67	3	2474.89	1.48	0.223	0.031
Right	Training age	86041.49	3	28680.50	24.39	0.0001*	0.348‡
	Field post	5695.98	3	1898.66	1.16	0.328	0.025
Left	Training age	64933.56	3	21644.52	17.48	0.0001*	0.277‡
	Field post	1233.26	3	411.09	0.26	0.864	0.005
Front	Training age	89837.69	3	29945.90	28.54	0.0001*	0.385‡
	Field post	2907.79	3	969.26	0.58	0.627	0.013
Rear	Training age	74597.65	3	24865.88	11.52	0.0001*	0.201‡
	Field post	6451.36	3	2150.45	1.32	0.272	0.028

Note. df – degree of freedom; F – value of ANOVA testing criterion; Sig – p value; p<0.05 are marked with an asterisk (*); † indicates moderate effect size (ηp²=0.06–0.13); ‡ indicates large effect size (ηp²≥0.14); BSRT = Brain Speed Reaction Time; BSE = Brain Speed Errors; BSQ = Brain Speed Quality; CDR = Complex Disjunctive Reaction Time; df – degree of freedom; Right/Left/Front/Rear = reaction time in the corresponding direction of the Fitro Agility Test.

Figures 1 and 2 illustrate the principal developmental patterns and effect sizes for practical interpretation.

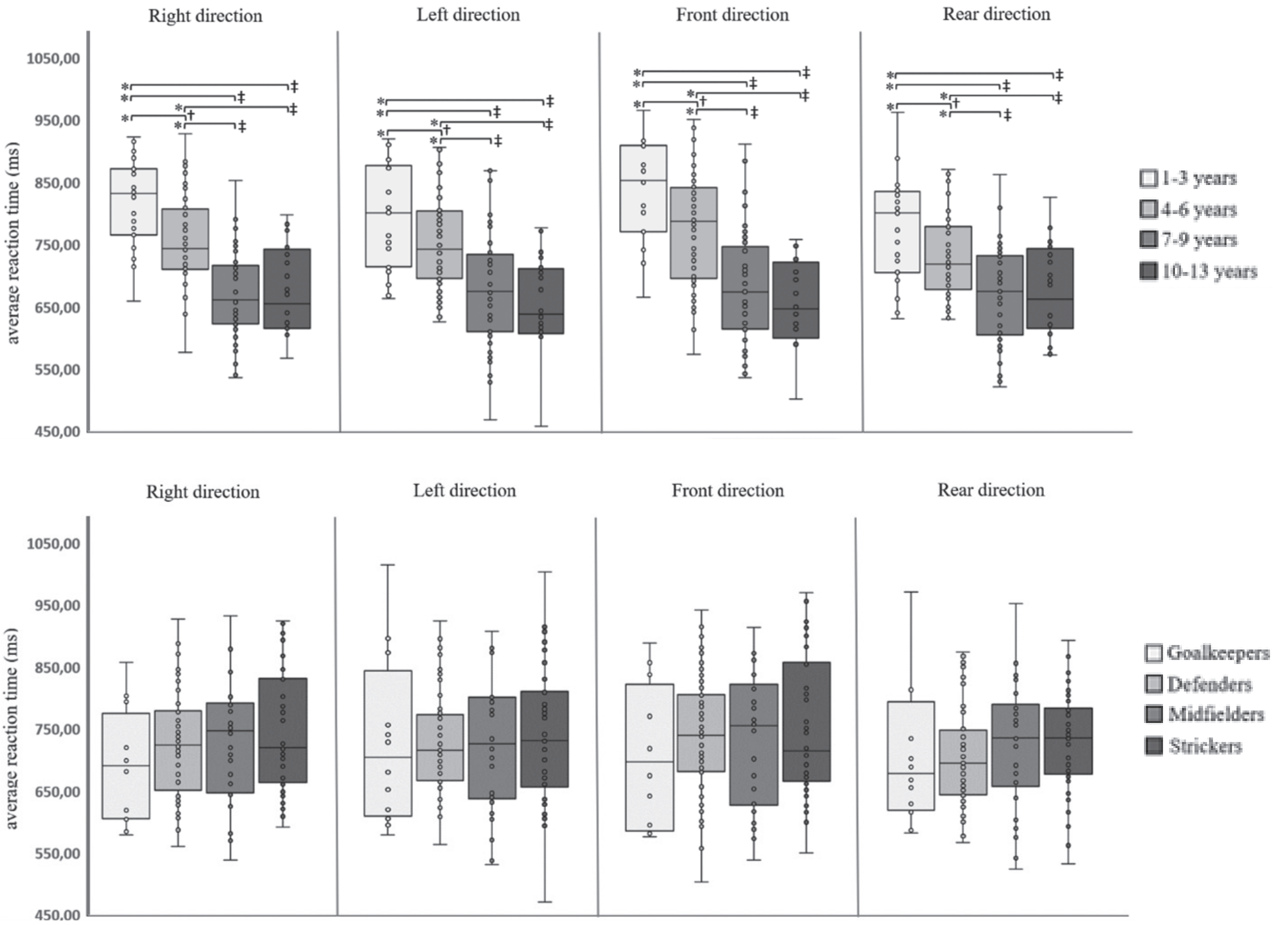

Figure 1. Comparison of reaction time in four movement directions (right, left, front, rear) across training age groups and field positions with identified significant differences based on post hoc analysis

*Note. Training age showed large effects across all agility directions, with TA7–9 and TA10–13 groups outperforming TA1–3. Positional trends were small and non-significant. LSD = Least Significant Difference test. Cohen's d effect size: † moderate (0.5≤d<0.8), ‡ large (d≥0.8).; * = statistically significant differences are indicated at p<0.05.*

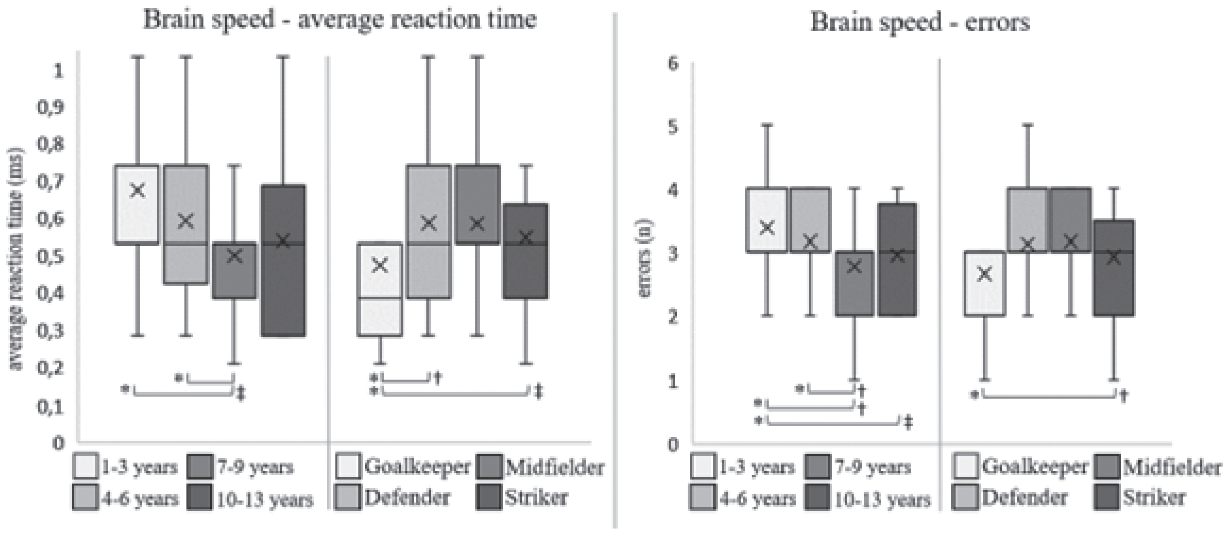

Figure 2. Graphical comparison of performance in brain speed and disjunctive reactivity tasks in relation to training age and field position

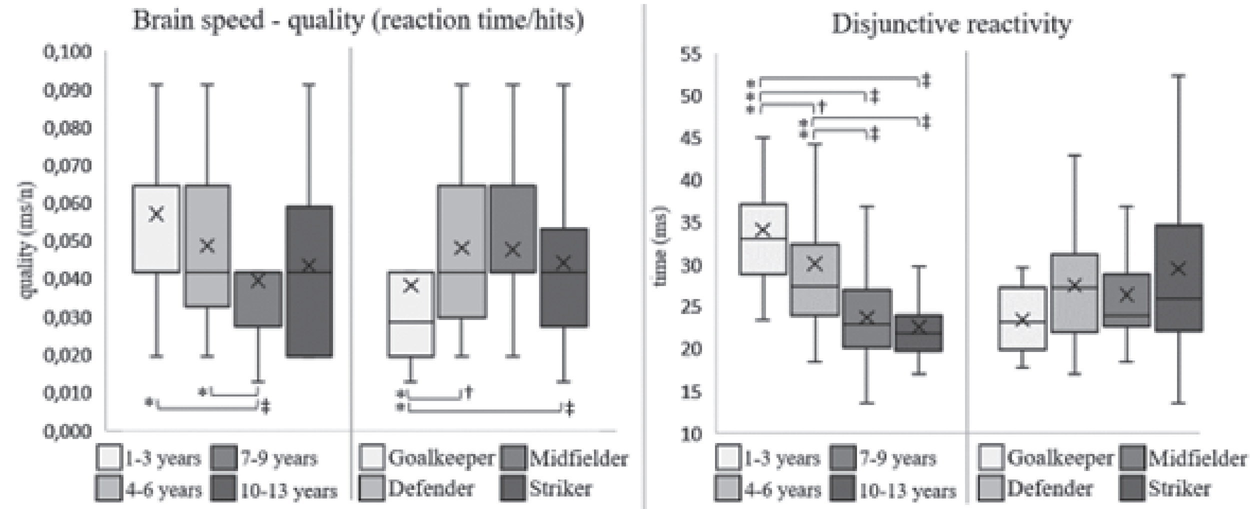

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Figure 2. Graphical comparison of performance in brain speed and disjunctive reactivity tasks in relation to training age and field position

*Note. Large effects of training age were observed for BSRT, BSQ and CDR. LSD = Least Significant Difference test. Cohen's d effect size: † moderate (0.5≤d<0.8), ‡ large (d≥0.8).; * = statistically significant differences are indicated at p<0.05.*

Discussion

Development of cognitive-motor abilities by training age

Our findings show a clear developmental progression in cognitive-motor performance associated with training experience. Players with longer sport experience demonstrated faster brain speed reaction times (BSRT), higher brain speed quality (BSQ), and improved directional agility. These results are in line with previous findings highlighting the importance of cumulative sport experience in improving reaction time and agility in youth athletes (Andrašić et al., 2021; Klatt et al., 2021). Moreover, recent evidence confirms that regular football training enhances executive functions such as working memory and inhibitory control (Mao et al., 2024), aligning with our data. Progressive improvements observed across training age groups reflect both neurodevelopmental maturation and the impact of structured cognitive-motor training (Feraco & Meneghetti, 2022). Such gains likely stem from enhanced attentional control and neural efficiency developed through repeated cognitive-motor exposure. The interpretation corresponds with the SMART COMPASS framework, which emphasizes that structured, autonomy-supportive motor learning fosters long-term brain adaptability (Klotzbier & Schott, 2025). Evidence from Meha et al. (2024) further supports this view. Their study showed cognitive benefits, especially in attention and memory, through age-appropriate programs like FUNBALL. Taken together, our results highlight the synergy of biological and experiential factors in adolescent motor-cognitive development (Abarghoueinejad et al., 2021; Bernate et al., 2024).

Positional differences in visual reaction and cognitive efficiency

Playing position did not have statistically significant effects; however, small-to-medium effect sizes indicated minor, non-significant positional tendencies. Midfielders tended to show the fastest BSRT, goalkeepers had the fewest brain speed errors (BSE), and defenders showed the highest BSQ values. These trends partially align with studies identifying higher cognitive load and sustained attention demands in midfield positions (Habekost et al., 2024). Goalkeepers' superior error monitoring may relate to the anticipatory demands of their role (Moreira et al., 2020). Similar positional tendencies have been reported in other studies (Li et al., 2024; Peñalosa et al., 2022), but given the limited sample size of some subgroups, these findings should be interpreted as exploratory rather than conclusive.

Directional agility and disjunctive reaction – age- and position-specific patterns

Our results revealed significant age-related improvements in directional agility, with the TA10–13 group outperforming all others across movement directions. This finding aligns with previous research emphasizing the contribution of neuromotor maturation and accumulated training experience (Thieschäfer & Büsch, 2022). Notably, TA1–3 players responded significantly slower in rear direction, suggesting developmental asymmetries in bilateral coordination. Such directional asymmetries may indicate incomplete neuromotor integration or lateralized attentional control, potentially increasing the risk of movement imbalance or injury if not addressed through targeted training. These results reinforce the concept of direction-specific motor development (Cartón-Llorente et al., 2024) and highlight the importance of incorporating age-appropriate and multidirectional agility drills (Trecroci et al., 2016). Positional differences in agility were not statistically significant, but descriptive patterns indicated that strikers had faster forward responses and midfielders showed relatively faster rear-direction responses. These tendencies align with the multidimensional agility framework proposed by Dos'Santos and Jones (2022), which links perceptual, biomechanical, and positional factors. Importantly, directional asymmetries identified in younger players may have implications for neuromotor development and injury prevention strategies (Arboix-Alió et al., 2024; Haddad, 2024; Wilkerson et al., 2017).

Visual error processing and brain speed quality (BSQ)

BSQ values improved significantly with training age, suggesting increased visual efficiency and attentional control. Older and more experienced players demonstrated faster processing with fewer errors. These results are consistent with Klatt et al. (2021), who found that experienced youth athletes exhibit lower visual error rates, reflecting more efficient attentional processing. Our data support the use of cognitive-motor assessments (e.g., BSQ) as indicators of training-induced efficiency. Previous work confirms that dual-task and sports-vision interventions enhance attention and decision-making (Ducrocq et al., 2016; Lochhead et al., 2024), supporting BSQ as a practical marker of perceptual-motor integration and cognitive efficiency.

Limitations, application and future directions

This study has several limitations. First, its cross-sectional design limits causal interpretation. Second, uneven subgroup sizes, especially for goalkeepers, restrict generalizability of position-related findings. Third, although Witty SEM and Fitro Agility provide valid measures of motor-cognitive performance, they may not fully capture sport-specific perceptual demands. Finally, despite uniform motivation procedures, individual effort could have introduced variability.

The current findings emphasize the value of integrating perceptual-cognitive diagnostics into youth football training. Players with lower training age demonstrated slower responses, particularly in disjunctive reaction time and rear-direction agility, suggesting the need for targeted interventions to support neuromotor development in these domains. Although positional differences were not statistically significant, the observed tendencies indicate potential cognitive specialization related to field roles, highlighting the importance of individualized, cognitively loaded training. From a practical standpoint, coaches and talent scouts can apply indicators such as BSRT, BSQ, and directional agility to monitor cognitive efficiency and detect developmental lags. Implementing drills targeting rear-direction reactions, visual scanning, and response inhibition may enhance neuromotor control and reduce asymmetry-related injury risk. Diagnostic systems such as Witty SEM and Fitro Agility provide reliable tools for player profiling, and future longitudinal research should examine their use in monitoring developmental trajectories and neuromotor resilience.

Conclusion

This study demonstrated that brain speed, reaction quality, and lower-limb agility significantly improve with increasing training age in youth soccer players. Large effect sizes in both cognitive (BSRT, BSQ) and motor (CDR, Fitro Agility) indicators suggest substantial neuromotor development between the ages of 7 and 13, with the most pronounced improvements observed in directional agility and brain speed quality. Although positional differences did not reach statistical significance, midfielders showed faster brain reaction times and defenders demonstrated higher brain speed quality, indicating possible neuromotor adaptations based on field roles. These findings emphasize the importance of incorporating cognitive-motor diagnostics into youth soccer training and support the implementation of age-appropriate and directionally targeted drills to enhance reactive performance.

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Conflict of interest
The authors declare that there is no conflict of interest with any financial organization in relation to the research problem discussed in the manuscript.

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Ethical approval information
Measurements were taken according to the ethical standards of the Declaration of Helsinki. The research was approved by Ethical Commission of University of Prešov (ECUP032023PO). Participation in the study was fully voluntary and anonymous. A participant's legal guardian received a written description of the study procedures before testing and submitted a written informed consent to participate in this study.

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References

Abarghoueinejad, M., Baxter-Jones, A. D. G., Gomes, T. N., Barreira, D., & Maia, J. (2021). Motor performance in male youth soccer players: A systematic review of longitudinal studies. *Sports, 9*(4), 53. https://doi.org/10.3390/sports9040053

Andrašić, S., Gušić, M., Stanković, M., Mačak, D., Bradić, A., Sporiš, G., & Trajković, N. (2021). Speed, change of direction speed and reactive agility in adolescent soccer players: Age-related differences. *International Journal of Environmental Research and Public Health, 18*(11), 5883. https://doi.org/10.3390/ijerph18115883

Arboix-Alió, J., Buscà, B., Miró, A., Bishop, C., & Fort-Vanmeerhaeghe, A. (2024). Ground reaction forces, asymmetries and performance of change of direction tasks in youth elite female basketball players. *Sports, 12*(1), 21. https://doi.org/10.3390/sports12010021

Bernate, J., Rojas, L., & Mendoza, J. (2024). Influencia de las habilidades físicas básicas en el proceso cognitivo: Una revisión sistemática. *Retos, 54,* 101819. https://doi.org/10.47197/retos.v54.101819

Cartón-Llorente, A., Cardiel-Sánchez, S., Molina-Molina, A., Ráfales-Perucha, A., & Rubio-Peirotén, A. (2024). Bilateral asymmetry of spatiotemporal running gait parameters in U14 athletes at different speeds. *Sports, 12*(5), 117. https://doi.org/10.3390/sports12050117

Chaouachi, A., Chtara, M., Hammami, R., Chtara, H., Turki, O., & Castagna, C. (2014). Multidirectional sprints and small-sided games training effect on agility and change of direction abilities in youth soccer. *Journal of Strength and Conditioning Research, 28*(11), 3121–3129. https://doi.org/10.1519/JSC.0000000000000505

Demir, O., & Kiyici, F. (2023). Investigation of the relationship of cognitive performance, visual reaction time and agility parameters on football players. *Spormetre Beden Eğitimi ve Spor Bilimleri Dergisi, 21*(3), 85–94. https://doi.org/10.33689/spormetre.1255170

Dos'Santos, T., & Jones, P. A. (2022). Training for change of direction and agility. *In Strength and conditioning for sports performance* (pp. 357–372). https://doi.org/10.4324/9781003044734-22

Ducrocq, E., Wilson, M. R., Vine, S. J., & Derakshan, N. (2016). Training attentional control improves cognitive and motor task performance. *Journal of Sport & Exercise Psychology, 38*(5), 521–533. https://doi.org/10.1123/JSEP.2016-0052

Feraco, T., & Meneghetti, C. (2022). Sport practice, fluid reasoning, and soft skills in 10- to 18-year-olds. *Frontiers in Human Neuroscience, 16,* 857412. https://doi.org/10.3389/fnhum.2022.857412

Friebe, D., Banzer, W., Giesche, F., Haser, C., Hülsdünker, T., Pfab, F., . . . Vogt, L. (2024). Effects of 6-week motor-cognitive agility training on football test performance in adult amateur players – A three-armed randomized controlled trial. *Journal of Sports Science and Medicine, 23*(3), 276–284. https://doi.org/10.52082/jssm.2024.276

Habekost, T., Ovesen, J., & Madsen, J. B. (2024). Cognition in elite soccer players: A general model. *Frontiers in Psychology, 15,* 1477262. https://doi.org/10.3389/fpsyg.2024.1477262

Horická, P., & Šimonek, J. (2021). Age-related changes of reactive agility in football. *Physical Activity Review, 9*(1), 16–23. https://doi.org/10.16926/par.2021.09.03

Horníková, H., Hadža, R., & Zemková, E. (2024). The contribution of perceptual-cognitive skills to reactive agility in early and middle adolescent soccer players. *Journal of Strength and Conditioning Research.* Advance online publication. https://doi.org/10.1519/jsc.0000000000004997

Klatt, S., & Nerb, J. (2021). Position-specific attentional skills in team sports: A comparison between defensive and offensive football players. *Applied Sciences, 11*(13), 5896. https://doi.org/10.3390/APP11135896

Klatt, S., & Smeeton, N. J. (2021). Processing visual information in elite junior soccer players: Effects of chronological age and training experience on visual perception, attention, and decision making. *European Journal of Sport Science, 21*(7), 933–941. https://doi.org/10.1080/17461391.2021.1887366

Klotzbier, T. J., & Schott, N. (2025). Scaffolding theory of maturation, cognition, motor performance, and motor skill acquisition: A revised and comprehensive framework for understanding motor–cognitive interactions across the lifespan (SMART COMPASS). *Frontiers in Human Neuroscience, 19,* 1631958. https://doi.org/10.3389/fnhum.2025.1631958

Li, J., Cao, Y., Huang, M., Li, Z., Qin, Z., & Lang, J. (2024). The alterations of functional brain networks and its relationship with sport decision-making and training duration in soccer players across different skill levels. *Neuroscience Letters, 818,* 137788. https://doi.org/10.1016/j.neulet.2024.137788

Lochhead, L., Feng, J., Laby, D. M., & Appelbaum, L. G. (2024). Training vision in athletes to improve sports performance: A systematic review of the literature. *International Review of Sport and Exercise Psychology.* https://doi.org/10.1080/1750984x.2024.2437385

Lucia, S., Digno, M., Madinabeita, I., & Russo, F. D. (2024). Integration of cognitive-motor dual-task training in physical sessions of highly-skilled basketball players. *Journal of Sports Sciences, 42*(10), 1201–1210. https://doi.org/10.1080/02640414.2024.2408191

Machado, G., González-Víllora, S., Roca, A., & Teoldo, I. (2024). Developing cognitive and motor decision-making skills through tactical principles and small-sided games in youth soccer. *International Journal of Performance Analysis in Sport, 24*(3), 205–219. https://doi.org/10.1080/24748668.2024.2321039

Mao, F., Yin, A., Zhao, S., & Fang, Q. (2024). Effects of football training on cognitive performance in children and adolescents: A meta-analytic review. *Frontiers in Psychology, 15,* 1449612. https://doi.org/10.3389/fpsyg.2024.1449612

Meha, R., Obërtinca, R., der Fünten, K. A., Kai, L., & Schaefer, S. (2024). A new injury prevention program 'FUNBALL' improves cognitive performance of young football (soccer) players: A cluster randomized controlled trial. *Psychology of Sport and Exercise, 71,* 102743. https://doi.org/10.1016/j.psychsport.2024.102743

Microgate S.r.l. (2019). *Witty SEM: User Manual (Version 1.6)*. Bolzano, Italy: Microgate S.r.l. Available at: https://training.microgate.it/sites/default/files/manuali/Witty-UserManual-EN.pdf

Moreira, P. E. D., Sousa, R. B. e, Morales, J. C. P., Greco, P. J., Arroyo, M. P. M., & Praça, G. M. (2020). Comportamiento táctico de jugadores de fútbol de diferentes posiciones, durante una temporada deportiva. *Retos, 39,* 424–431. https://doi.org/10.47197/RETOS.V0I39.75970

Peñalosa, A. S., López, E. R., Garrido, R. E. R., Baro, J. P. M., Diz, J. A. V., Mendo, A. H., & Sánchez, V. M. (2022). Funcionamiento cognitivo y rendimiento deportivo en jóvenes futbolistas: Una revisión sistemática. *Cuadernos de Psicología del Deporte, 22*(3), 32–52. https://doi.org/10.6018/cpd.494741

Ramsey, H., Dicks, M., Reddy, V., & Hope, L. (2024). Decision-making in action: How international-level professional football players gain an advantage. *Psychology of Sport and Exercise, 70,* 102722. https://doi.org/10.1016/j.psychsport.2024.102722

Rodrigues, M. C. J., Figueiredo, L. S., Lira, C. A. B. D., Laporta, L., & Costa, G. D. C. T. (2022). Cognitive processes in small-sided games. *Retos, 44,* 681–688. https://doi.org/10.47197/retos.v44i0.90369

Scharfen, H.-E., & Memmert, D. (2019). The relationship between cognitive functions and sport-specific motor skills in elite youth soccer players. *Frontiers in Psychology, 10,* 817. https://doi.org/10.3389/fpsyg.2019.00817

Thieschäfer, L., & Büsch, D. (2022). Development and trainability of agility in youth: A systematic scoping review. *Frontiers in Sports and Active Living, 4,* 952779. https://doi.org/10.3389/fspor.2022.952779

Trecroci, A., Duca, M., Cavaggioni, L., Rossi, A., Scurati, R., Longo, S., . . . & Formenti, D. (2021). Relationship between cognitive functions and sport-specific physical performance in youth volleyball players. *Brain Sciences, 11*(2), 227. https://doi.org/10.3390/brainsci11020227

Vasile, A., Alexandru, A., & Andrei, M. (2024). Cognitive-motor agility and decision-making in youth: Witty SEM System and Cognitrom Assessment System. *Annals of Applied Sport Science, 12*(1). http://aassjournal.com/article-1-1323-en.html

Wilkerson, G. B., Simpson, K. A., & Clark, R. A. (2017). Assessment and training of visuomotor reaction time for football injury prevention. *Journal of Sport Rehabilitation, 26*(1), 26–34. https://doi.org/10.1123/JSR.2015-0068

Zemková, E., & Hamar, D. (2013). Reaction time in the agility test under simulated competitive and non-competitive conditions. *Journal of Human Kinetics, 37*(1), 5–13. https://doi.org/10.2478/hukin-2013-0019