ORIGINAL ARTICLE

Specific features of cognitive skill development in athletes of situational sports

Vyacheslav Romanenko[1ABCDE], Yrui Tropin[1ABCD], Leonid Podrigalo[1ACD], Natalya Boychenko[1ABD], Anatoly Abdula[1BCD], Nataliia Sereda[1BCD], Yaroslav Yatsiv[2CDE]

[1] *Kharkiv State Academy of Physical Culture, Ukraine*

[2] *Vasyl Stefanyk Precarpathian National University, Ukraine*

Authors' Contributions: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript preparation; E – Funds Collection.

Abstract

Background and Study Aim The formation of cognitive skills in athletes engaged in situational sports follows specific patterns determined by the characteristics of gameplay or competitive activity, as well as by the influence of psychophysiological and individual traits. An equally important factor in the development of cognitive skills is the training process, which incorporates specialized exercises and techniques aimed at stimulating cognitive processes, situational analysis, spatial imagination, and adaptive behavior. This study aimed to identify the peculiarities of cognitive skill formation in athletes participating in situational sports.

Material and Methods The study involved 97 participants, including 80 qualified male athletes with 5 to 9 years of training experience, representing three sports: football (n = 26, age 15.3 ± 0.49 years), judo (n = 31, age 16.6 ± 2.83 years), and taekwondo (n = 23, age 16.5 ± 1.90 years), and 17 boys (age 8.71 ± 1.16 years) who were not engaged in organized sports but expressed interest in doing so. Psychophysiological testing was conducted using tablet-based applications on iOS devices: the "Spatial Perception" test was used to assess spatial perception, and the "TestSTMemory" was used to evaluate short-term visual memory. Mathematical and statistical analyses were conducted using RStudio. Linear discriminant analysis was applied to differentiate athletes by sport. Wilks' Lambda was used to evaluate the quality of the discriminant model. Analysis of variance (ANOVA) was performed to identify variables with significant intergroup differences. The Kruskal–Wallis test was used to assess the reliability of differences between the studied groups.

Results The results of the short-term visual memory test indicate that the differences between the study groups, as assessed by the Kruskal–Wallis test, were not statistically significant ($p > 0.05$). In the spatial perception test, statistically significant differences were observed only at the fourth stage, in the percentage of errors (p-value = 0.01). The results of the discriminant analysis show that, when constructing a linear discriminant analysis (LDA) model with three classes (football, judo, taekwondo), two discriminant functions were identified, explaining 62% (LD1) and 38% (LD2) of the variance between the groups, respectively. The Wilks' Lambda = 0.455 indicates statistically significant differences between the groups ($F = 1.611$, $p = 0.0295$). Model testing confirmed high accuracy in classifying respondents according to their respective sports profiles: judo (0.88 ± 0.11) and football (0.98 ± 0.03).

Conclusions Situational sports, including team sports and martial arts, require athletes to demonstrate a high level of executive functions. The development of these functions follows specific patterns influenced by the nature of sports activity. The characteristics of short-term visual memory and spatial perception in football, judo, and taekwondo athletes were identified. Based on discriminant analysis of the psychophysiological testing results, a model with a predictive accuracy of 72.5% was developed, allowing for the classification of respondents into their respective sport groups (football, judo, taekwondo). Analysis of variance revealed that statistically significant differences between the groups are associated with indicators related to spatial perception. The findings confirm that spatial perception exhibits distinct features depending on the type of sport.

Keywords: psychophysiological indicators, cognitive skills, qualified athletes, children, judo, taekwondo, football.

Introduction

The modern sports environment is characterized by rapid development and increasing complexity of competitive activities, which demand of athletes not only physical, technical, and tactical excellence, but also a high level of psychophysiological skill development [1, 2]. The study of psychophysiological indicators has attracted considerable interest among researchers worldwide [3, 4]. The investigation of cognitive processes in situational sports is of particular relevance, as athletic performance largely depends on the ability to quickly perceive, analyze,

doi:10.15561/26649837.2025.0305

and interpret information in a constantly changing competitive context [5].

Situational sports, including team games and martial arts, are marked by a high degree of unpredictability and the necessity to make decisions under time pressure. In such conditions, cognitive skills such as attention, memory, perception, thinking, anticipation, and decision-making are critical for achieving effective athletic performance [6]. Athletes with well-developed cognitive abilities demonstrate superior decision-making and more adaptive, positive thinking [7, 8].

The scientific community is increasingly focusing on the cognitive component of athletes' preparedness. Several studies have investigated the mechanisms of visual information processing, cognitive flexibility, and stress resistance in athletes across various sports disciplines [9]. Research has also explored the impact of fatigue on athletes' perceptual and cognitive performance [10]. Other studies have assessed cognitive abilities in relation to age, anthropometric parameters, physical fitness, and technical skills in young athletes [11], as well as sports experience [12]. At the same time, the formation of cognitive skills in athletes engaged in situational sports follows specific patterns shaped by the nature of gameplay or competitive activity, as well as by the influence of psychophysiological and individual characteristics [13, 14].

An equally important factor in cognitive skill development is the training process, which incorporates specialized exercises and techniques aimed at stimulating cognitive functions, situational analysis, spatial imagination, and adaptive behavior [15, 16]. Modern technologies enhance this process through cognitively oriented training methods, including virtual and augmented reality, computer programs, and simulation training devices that replicate real-game scenarios [17].

Another critical aspect is the influence of individual psychological characteristics on the effectiveness of cognitive skill development [18, 19]. Researchers highlight the roles of motivation, personality traits, thinking styles, and prior sports experience as key determinants of cognitive development [20].

The study of the peculiarities of cognitive skill formation in situational sports contributes to a deeper understanding of the patterns governing cognitive functioning in athletes. It enables the identification of optimal pathways for cognitive development and the implementation of effective methods within the training process. These insights offer promising opportunities for enhancing the sports training system and improving athletes' competitiveness on the international stage.

Purpose of the Study: To identify the specific features of cognitive skill development in athletes engaged in situational sports.

Material and Methods

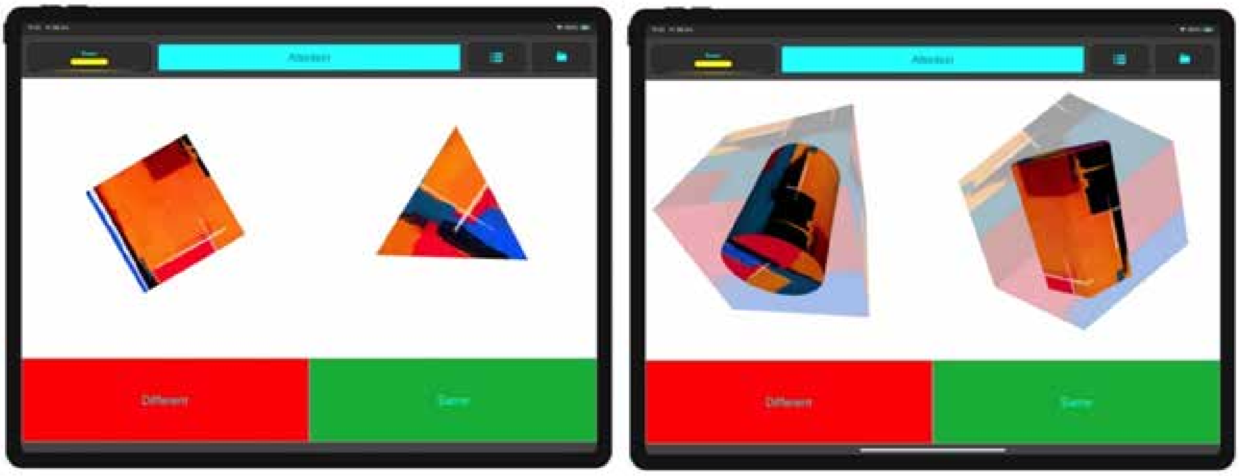
Participants

The study involved 97 participants, including 80 qualified male athletes with 5 to 9 years of training experience, representing three sports: football (n = 26, age 15.3 ± 0.49 years), judo (n = 31, age 16.6 ± 2.83 years), and taekwondo (n = 23, age 16.5 ± 1.90 years). To test the developed model, data were also collected from 17 boys (age 8.71 ± 1.16 years) who had not yet chosen a specific sport. All participants provided informed consent to take part in the study and were informed about its objectives, testing procedures, and their right to withdraw at any time without penalty. For underage participants, informed consent for psychophysiological testing was obtained from their parents, who were present during the assessment. At the time of the study, all participants were in good health. All procedures were carried out in accordance with fundamental bioethical principles, including the Council of Europe Convention on Human Rights and Biomedicine (04.04.1997), the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects (1964–2008), and the Order of the Ministry of Health of Ukraine No. 690 dated 23.09.2009.

Research Design

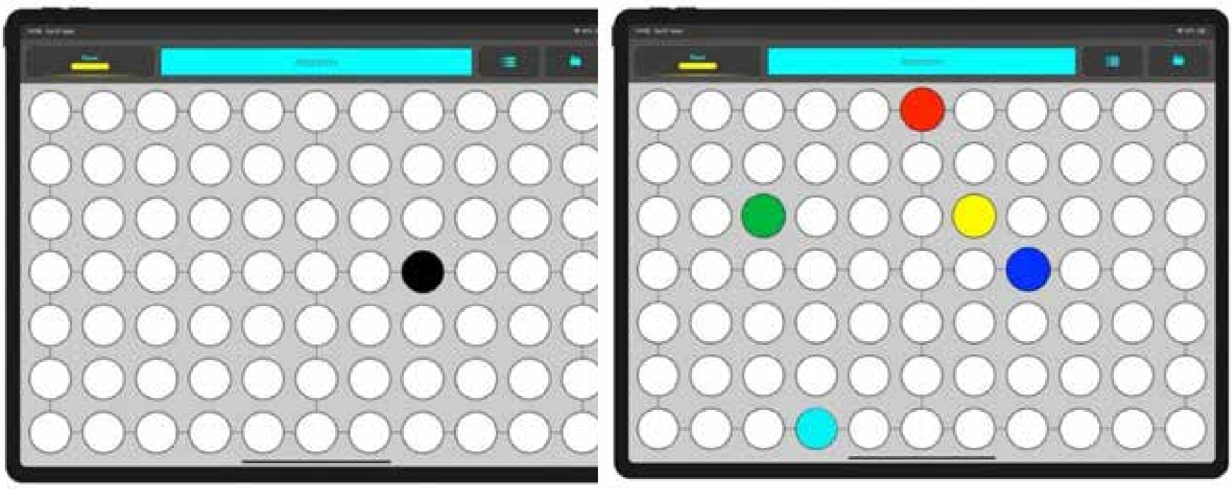
Psychophysiological testing was conducted using specialized applications for mobile devices running iPadOS. Spatial perception was assessed using the "Spatial Perception" test, and short-term visual memory was evaluated using the "TestSTMemory" application. These tests have been validated in previous studies [19, 21]. The spatial perception test consisted of four stages involving the rapid recognition of geometric shapes. In the first stage, participants were required to recognize two-dimensional objects (square, rhombus, hexagon, circle, triangle). The second stage involved the identification of static three-dimensional objects (cube, cylinder, sphere, hexagonal prism, octahedron). The third stage assessed the recognition of dynamic three-dimensional objects, and the fourth stage presented dynamic three-dimensional objects with visual distractors (Fig. 1). During the task, participants selected the appropriate response by tapping the screen. If the shapes were identical, they tapped "Same" (green circle); if the shapes differed, they tapped "Different" (red circle).

The computer program "TestSTMemory," designed to assess short-term visual memory, consisted of five stages, each comprising 10 trials (Fig. 2). In the first stage, participants were required to respond to a single monochromatic visual stimulus in the first five trials by memorizing its location and tapping the corresponding circle. In the subsequent five trials, they responded to



2D shapes (first stage) 3D shapes (fourth stage)

Figure 1. Interface of the computer program "Spatial Perception"



First stage Fifth stage

Figure 2. Interface of the computer program "TestSTMemory"

stimuli of different colors. At each following stage, the number of simultaneously presented stimuli increased by one. By the fifth stage, participants had to memorize the positions of five stimuli and tap the corresponding circles. To evaluate short-term visual memory, a memory coefficient was calculated as the ratio of correct responses to the total number of attempts. The duration of each visual stimulus was set at 300 ms.

Statistical analysis

Mathematical and statistical analyses were conducted using the RStudio software. To classify athletes into distinct groups based on their psychophysiological characteristics, linear discriminant analysis (LDA) was performed using the "MASS" package for discriminant analysis. To evaluate the model's quality within a multivariate context, Wilks' Lambda was calculated. The classification performance was assessed using key metrics: balanced accuracy, precision (positive predictive value), and recall (sensitivity), obtained via the *confusionMatrix()* function from the "caret" package in R. To identify variables with statistically significant differences between groups, analysis of variance (ANOVA) was applied. The Kruskal–Wallis test was used to assess the reliability of differences across the study groups where assumptions of parametric testing were not met.

Results

Eighteen numerical variables characterizing the level of cognitive skill performance at various stages of the test exercises were selected as independent predictors for the discriminant analysis. These included reaction time, number of errors (from the spatial perception test), trial duration, and the short-term visual memory coefficient (from the short-term visual memory test) (Tables 1 and 2).

The nonparametric Kruskal–Wallis test was used to identify differences between the study groups. The results of the short-term visual memory test indicated that differences across all stages were not statistically significant ($p > 0.05$). In contrast, the spatial perception test revealed statistically significant differences only at the fourth stage, specifically in the percentage of errors (p = 0.01). To determine which groups differed significantly, Dunn's test was performed (Table 3).

The results of the discriminant analysis indicate that, when constructing the LDA model with three classes (football, judo, taekwondo), two discriminant functions were identified, accounting for the variance between the groups: LD1 explained 62% and LD2 explained 38% of the total variation (Fig. 3).

Based on the values of the discrimination coefficients, we identified the numerical variables that had the greatest influence on class separation. These variables primarily included trial duration (i.e., the time required by participants to reproduce the location of visual stimuli) in the short-term visual memory test. The most influential factor for LD1 was the trial duration at stage 4 (coefficient = 3.981). Trial duration at stage 1 significantly contributed to both LD1 (−1.447) and LD2 (−6.686). Trial durations at stages 5, 3, and 2 also played a notable role in the differentiation of classes in the LDA model. According to the trial duration values, athletes in the football

Table 1. Values of group means (test: "Spatial Perception")

Group	Err1, %	Err2, %	Err3, %	Err4, %	R1, ms	R2, ms	R3, ms	R4, ms
Football (n=26)	8.846	9.423	5.385	6.923	739.996	788.423	801.577	844.777
Judo (n=31)	7.419	7.419	5.161	3.065	768.187	806.494	805.529	835.874
Taekwondo (n=23)	8.478	8.478	5.000	7.609	690.770	721.530	753.626	771.117

Err1 - errors on the first stage; Err2 - errors on the second stage; Err3 - errors on the third stage; Err4 - errors on the fourth stage; R1 - reaction time on the first stage; R2 - reaction time on the second stage; R3 - reaction time on the third stage; R4 - reaction time on the fourth stage.

Table 2. Values of group means (test: "TestSTMemory")

Group	D1, s	D2, s	D3, s	D4, s	D5, s	C1, %	C2, %	C3, %	C4, %	C5, %
Football (n=26)	0.648	1.009	1.373	1.753	2.160	99.615	98.654	93.4589	89.711	82.846
Judo (n=31)	0.681	1.027	1.422	1.838	2.346	99.032	98.226	93.768	85.726	81.097
Taekwondo (n=23)	0.701	1.056	1.456	1.909	2.305	100.000	97.608	94.343	88.370	82.087

D1 - duration of trial at the first stage; D2 - duration of trial at the second stage; D3 - duration of trial at the third stage; D4 - duration of trial at the fourth stage; D5 - duration of trial at the fifth stage; C1 - coefficient of short-term visual memory at the first stage; C2 - coefficient of short-term visual memory at the second stage; C3 - coefficient of short-term visual memory at the third stage; C4 - coefficient of short-term visual memory at the fourth stage; C5 - coefficient of short-term visual memory at the fifth stage.

Table 3. Differences between the groups (test: "Spatial Perception", stage 4, percentage of errors)

Comparison	Z-statistics	p-value
Judo vs Football	2.578	0.015
Taekwondo vs Judo	-2.626	0.013
Taekwondo vs Football	-0.130	1.000

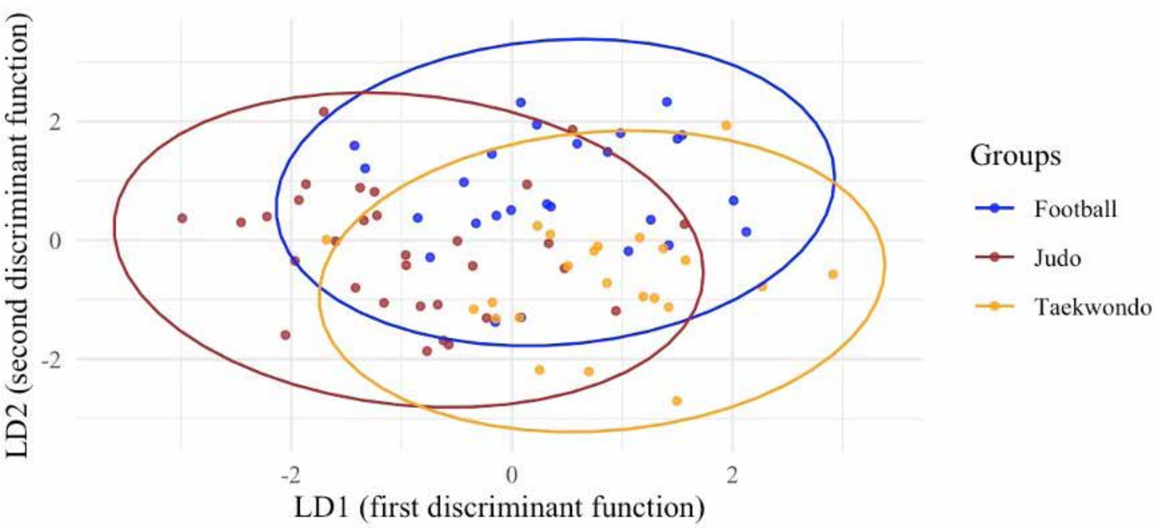


Figure 3. Discriminant analysis: LD1 vs LD2

group demonstrated the shortest average response time (1.39 s) and the highest percentage of correct answers (92.9%). The taekwondo group showed the longest average duration (1.49 s) with a moderate accuracy rate (92.5%). The judo group recorded the lowest accuracy (91.6%) with an intermediate trial duration (1.46 s).

The discriminant analysis yielded a classification accuracy of 72.5%, indicating a satisfactory ability to distinguish among athletes from the three sports (football, judo, taekwondo) (table 4). Specifically, 16 out of 26 observations (61.5%) were correctly classified in the football group, 25 out of 31 (80.6%) in the judo group, and 17 out of 23 (73.9%) in the taekwondo group. The Wilks' Lambda value = 0.455 (F = 1.611, p = 0.0295) indicates statistically significant differences among the groups, suggesting that the model reliably distinguishes between the athlete groups based on the selected predictors, especially between judo and taekwondo, where balanced accuracy exceeded 0.8 (Fig. 4).

According to the results of the analysis of variance, statistically significant differences between the studied groups were found in the indicators reflecting athletes' levels of spatial perception (Table 5).

The model (LDA) was tested using indicators of psychophysiological measurements of children (n = 17) who had not yet chosen a sport for regular training (Fig. 4).

The analysis of predictive classification results indicates that several children (1, 2, 7, 9, 10, 13, 14, 16, 17) exhibit cognitive characteristics closely aligned with the judo profile (mean probability = 0.88 ± 0.11). Children 3, 4, 5, and 15 correspond to the football profile (mean probability = 0.98 ± 0.03). Children 6 and 8 display mixed characteristics, falling between the football and judo profiles. Meanwhile, children 11 and 12 partially match the taekwondo profile. The classification results suggest that none of the tested children exhibited a clear predisposition toward the taekwondo profile.

Discussion

Situational sports, encompassing both martial arts and team sports, demand that athletes rapidly analyze evolving competitive contexts, make decisions in real time, and adapt their behavior to

Table 4. Model performance (confusion matrix)

Class	Balanced Accuracy	Precision (Pos Pred)	Recall (Sensitivity)
Football	0.743	0.696	0.615
Judo	0.822	0.758	0.807
Taekwondo	0.808	0.708	0.739

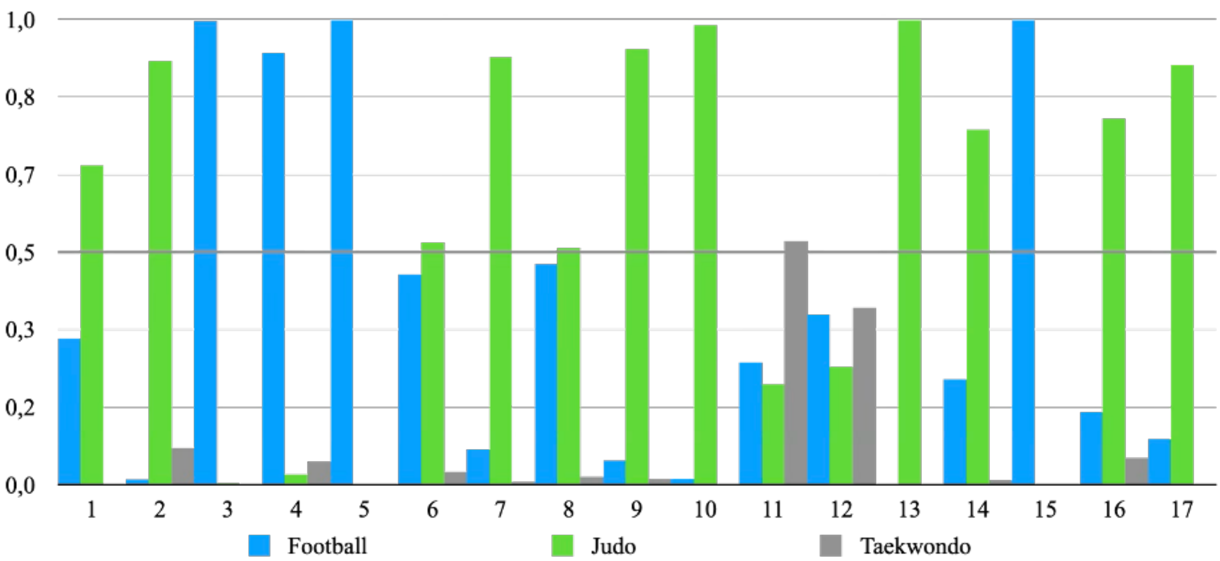


Figure 4. Prediction of class affiliation (n=17)

Table 5. Variations between classes (Analysis of Variance - ANOVA)

Indicators	Sum Sq	Mean Sq	F value	P-value
Reaction time on the first stage «Spatial Perception»	79538	39769	3.300	0.042
Reaction time on the fourth stage«Spatial Perception»	78730	39365	3.332	0.041
Errors on the fourth stage «Spatial Perception»	337.60	168.78	6.244	0.003

unpredictable conditions [1, 10]. Success in these sports depends on a high level of perceptual–intellectual and emotional–volitional capabilities, enabling effective performance amid dynamic environments [5, 22]. Core characteristics of situational sports include dynamic competitive conditions [4, 23, 24], elevated cognitive demands [9, 13], strong moral and volitional qualities [20, 25], and a creative approach to problem-solving [17, 26].

The study of cognitive skills provides insight into the mechanisms and characteristics of visual information processing among athletes from different sports disciplines [5, 10]. Research has established associations between cognitive functions, skill acquisition, and athletic performance [6]. According to [7], highly skilled athletes demonstrate a higher level of cognitive functioning compared to those with lower qualifications. However, their findings also suggest limited evidence supporting the predictive value of general executive functions for future sports performance. Executive functions constitute a broad category encompassing various cognitive abilities [27]. Evidence indicates that different sports may influence these functions in distinct ways [32]. Current research suggests that improvements in executive functioning are largely dependent on the motor demands specific to each sport [29, 30]. Sports such as martial arts and team games engage athletes in complex cognitive activities, including perception, attention, planning, strategy development, adjustment to changing conditions, continuous adaptation, and real-time decision-making [31]. Actions in these sports are performed in dynamic and unpredictable environments, fostering the development of cognitive functions such as attention, perception, and short-term visual memory [32, 33]. Further studies [34] have reported a strong correlation between participation in sports like basketball, martial arts, and football and higher mathematics achievement. This association is likely linked to the enhancement of spatial abilities, which contribute to mathematical problem-solving. However, the authors did not observe a significant effect on literacy outcomes among the participants, suggesting that these sports-related cognitive benefits are less relevant to the executive functions involved in reading and language processing.

This study used specialized computer programs for mobile devices running iPadOS. These programs were designed to assess short-term visual memory and spatial perception in martial artists. The test tasks within these programs create conditions that impose a cognitive load comparable to that of a sports match. For example, in the short-term visual memory test, participants must not only memorize the location of visual signals of the same color (black or monochrome circles of varying intensity) but also process signals of different colors, which requires additional cognitive effort [21]. The spatial perception test includes a task that involves quickly recognizing rotating 3D geometric shapes and responding accordingly. Another task requires recognizing 3D geometric shapes presented against a background of distracting visual stimuli. Such test tasks demand increased attention and concentration from the respondent and, as visual load increases, require a balance of nervous processes that supports rapid decision-making [19].

As noted in the results of the study, statistically significant differences (p-value = 0.01) between the study groups were found only in the percentage of errors on the fourth, most difficult stage of the "Spatial Perception" test. The lowest percentage of errors was shown by judokas (3.07%), the highest by representatives of the taekwondo group (7.61%), and an average percentage was shown by football players (6.92%). Moreover, taekwondo athletes demonstrated the best reaction time at this stage (771.1 ms), which is due to the specific demands of their activity, requiring rapid reactions during technical and tactical actions under active opponent pressure. A reduced reaction time affects the ability to cognitively process information, which decreases the accuracy of actions and increases the likelihood of errors [35]. The lower error rate among judokas may be due to the fact that, compared to other combat sports such as boxing or taekwondo, judo emphasizes the principles of "maximum efficiency, minimum effort" and "mutual benefit and prosperity." It has been noted that these principles can translate into cognitive benefits such as better impulse control, stress resistance, and an improved ability to make complex decisions [36].

For the discriminant analysis, 18 numerical variables were selected to characterize the level of cognitive skills of athletes. According to the results of the study, the numerical variable that most strongly influenced class separation was the duration of trials (i.e., the time spent by the respondent on reproducing the locations of visual stimuli) in the short-term visual memory test. The duration of the trial depends on the pace of the test exercise chosen by the subject. Each athlete selects a comfortable pace that allows them to retain the locations of visual stimuli in memory and respond accordingly. The duration of attempts also depends on the accuracy of clicking on the presented circles. Inaccurate clicking increases trial duration, while clicking on mismatched circles reduces the short-term visual memory coefficient. These indicators reflect the specific characteristics of visual information retention and the corresponding motor actions of the tested athletes. In the "TestSTMemory" test, the shortest trial duration (1.39 s) and the highest percentage of correct answers (92.9%) were shown by football players. Taekwondo athletes showed the longest trial duration (1.49 s) and a slightly lower accuracy rate (92.5%), while judo athletes had an average trial duration and the lowest percentage of correct answers (91.6%). A sufficiently high pace in completing the test task allowed football players to achieve the best result at the most difficult, fifth stage of the test (82.8%) compared to representatives of other sports. The authors of [13, 37] noted that elite football players demonstrate excellent perceptual and cognitive abilities. They show higher performance in tracking multiple objects compared to less skilled and younger athletes. In soccer, players operate on a large field where events unfold at a considerable distance. This provides slightly more time for decision-making compared to martial arts. However, the challenge lies in processing a large volume of information, such as the positions of teammates and opponents, ball trajectory, tactical schemes, and so on. This demands a high level of cognitive processing and decision-making in constantly changing situations [38].

The results of the analysis of variance indicate that athletes from different sports exhibit distinct characteristics in spatial perception. In the "Spatial Perception" test, football players demonstrated an average recognition time for geometric shapes of 793.7 ms and a relatively high error rate of 7.6%. Taekwondo athletes achieved the shortest recognition time (734.3 ms) and a moderate error rate (7.4%). Judokas exhibited the longest recognition time (804.0 ms) but the lowest error rate (5.8%).

The nature of striking martial arts, such as taekwondo, requires athletes to respond rapidly under conditions of continuous threat from an opponent's attacks (punches, kicks), often at close distances. This constant exposure to dynamic, high-stakes situations necessitates ongoing analysis of visual information. Competitive bouts stimulate targeted behavioral responses, which in turn foster improvements in cognitive functions such as visual selective attention, verbal working memory, and reaction time [39]. As noted in [19], martial artists employ a variety of strategies to recognize opponents' movements, with peripheral vision playing a critical role during matches [40]. Skilled athletes are believed to outperform non-athletes in processing and interpreting visual cues, drawing upon sport-specific perceptual strategies developed over the course of their training and competitive experience [41, 42].

Studies on reaction speed in judo reveal that response time is positively correlated with training experience [43]. Experienced judokas display reduced reaction times due to enhancements in both sensory latency and motor response [44]. This improvement is likely attributable to their adaptation to specialized training tasks, which reduce cognitive load and enhance attentional focus [45]. A unique feature of grappling sports such as judo is the emphasis on physical contact, where tactile feedback plays a prominent role. Tactile information is processed differently in the brain compared to visual or auditory stimuli. As a result, experienced judokas may possess superior tactile perception abilities relative to athletes in visually or acoustically dominant sports [43].

The results of the study show that the accuracy of the model created based on discriminant analysis was 72.5%. The model reliably distinguishes between groups, especially judokas and taekwondo athletes (Table 4). This model can be used for selecting children for a particular sport. The use of discriminant analysis in sports selection is supported by numerous studies demonstrating its high accuracy in classifying athletes by sport [46, 47, 48]. According to the analysis of psychophysiological indicators of boys (n = 17) who took part in testing the model, it is possible to recommend boys numbered 3, 4, 5, and 15 to try football (predicted probability: 98%). Boys numbered 1, 2, 7, 9, 10, 13, 14, 16, and 17 should be advised to join a judo section (predicted probability: 88%). The remaining children (numbers 6, 8, 11, and 12) exhibited mixed characteristics, so the model's predictive reliability for a particular sport was low (Fig. 4).

The results of the discriminant analysis require further research with larger samples to improve the accuracy of the model and its adaptation to different sports disciplines.

Conclusions

Situational sports, which include team games and martial arts, require athletes to demonstrate a high level of executive functions. The formation of these functions occurs according to specific patterns influenced by the nature of sports activity. The peculiarities of short-term visual memory and spatial perception in football, judo, and taekwondo athletes have been identified. Based on the discriminant analysis of the psychophysiological testing results of the studied athletes, a model with a predictive reliability of 72.5% was created, which allows for the classification of respondents into the corresponding groups (football, judo, taekwondo). The analysis of variance made it possible to determine that statistically significant differences between the studied groups are found in indicators characterizing athletes' spatial perception. It has been shown that spatial perception exhibits specific features depending on the type of sport.

Acknowledgement

The authors sincerely thank the participants who took part in this study and contributed to its implementation. This research received no funding.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Franchini E, Takito MY, Julio UF. Physiological, perceptual and performance variables partially predict pacing in judo. *International Journal of Performance Analysis in Sport*, 2023;23(5): 371–385. https://doi.org/10.1080/24748668.2023.2238166
2. Korobeynikov G, Korobeinikova L, Raab M, Korobeinikova I, Danko T, Kokhanevich A, Cynarski WJ, Mytskan T. Psychophysiological state and decision making in wrestlers. *Ido Movement for Culture. Journal of Martial Arts Anthropology*. 2022;22(5):1–9. https://doi.org/10.14589/ido.22.5.2
3. Eadie R. An Overview of Contemporary Scientific Research into the Physiological and Cognitive Benefits of Judo Practice. *Martial Arts Studies*, 2023;(14): 78–82. https://doi.org/10.18573/mas.160
4. Romanenko V, Podrigalo L, Iermakov S, Rovnaya O, Tolstoplet E, Tropin Y, et al. Functional state of martial arts athletes during implementation process of controlled activity - comparative analysis. *Physical Activity Review*, 2018;6: 87–93. https://doi.org/10.16926/par.2018.06.12
5. Biedrzycki J, Laskowski R. The impact of judo training on the development of cognitive functions – A systematic review. *Balt J Health Phys Act.* 2024;16(4):7. https://doi.org/10.29359/BJHPA.16.4.07
6. Korobeynikov G, Korobeinikova L, Raab M, Baić M, Borysova O, Korobeinikova I, et al. Cognitive functions and special working capacity in elite boxers. *Pedagogy of Physical Culture and Sports*, 2023;27(1): 84–90. https://doi.org/10.15561/26649837.2023.0110
7. Kalén A, Bisagno E, Musculus L, Raab M, Pérez-Ferreirós A, Williams AM, et al. The role of domain-specific and domain-general cognitive functions and skills in sports performance: A meta-analysis. *Psychological Bulletin*, 2021;147(12): 1290–1308. https://doi.org/10.1037/bul0000355
8. Ishak MA, Mohd Kassim AF, Miswan MS, Zainuddin NF. The Comparison of Decision-Making Skills between Athletes and Non-athletes among University Students. *Journal of Human Centered Technology*, 2023;2(1): 73–77. https://doi.org/10.11113/humentech.v2n1.42
9. Conejero Suárez M, Prado Serenini AL, Fernández-Echeverría C, Collado-Mateo D, Moreno Arroyo MP. The Effect of Decision Training, from a Cognitive Perspective, on Decision-Making in Volleyball: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health*, 2020;17(10): 3628. https://doi.org/10.3390/ijerph17103628
10. Dong L, Pageaux B, Romeas T, Berryman N. The effects of fatigue on perceptual-cognitive performance among open-skill sport athletes: A scoping review. *International Review of Sport and Exercise Psychology*, 2024;17(2): 1170–1221. https://doi.org/10.1080/1750984X.2022.2135126
11. Paśko W, Śliż M, Paszkowski M, Zieliński J, Polak K, Huzarski M, et al. Characteristics of Cognitive Abilities among Youths Practicing Football. *International Journal of Environmental Research and Public Health*, 2021;18(4): 1371. https://doi.org/10.3390/ijerph18041371
12. Logan NE, Henry DA, Hillman CH, Kramer AF. Trained athletes and cognitive function: a systematic review and meta-analysis. *International Journal of Sport and Exercise Psychology*, 2023;21(4): 725–749. https://doi.org/10.1080/1612197X.2022.2084764
13. Ehmann P, Beavan A, Spielmann J, Mayer J, Altmann S, Ruf L, et al. Perceptual-cognitive performance of youth soccer players in a 360°-environment – Differences between age groups and performance levels. *Psychology of Sport and Exercise*, 2022;59: 102120. https://doi.org/10.1016/j.psychsport.2021.102120
14. Elferink-Gemser MT, Faber IR, Visscher C, Hung TM, De Vries SJ, Nijhuis-Van Der Sanden MWG. Higher-level cognitive functions in Dutch elite and sub-elite table tennis players. Ardigò LP (ed.) *PLOS ONE*, 2018;13(11): e0206151. https://doi.org/10.1371/journal.pone.0206151
15. Piatysotska S, Mulyk V, Huba A, Dolgopolova N, Yefremenko A, Zhernovnikova Y. Study of the psychomotor abilities of athletes in cyclic sports, martial arts and esports. *Slobozhanskyi Herald of Science and Sport*, 2023;27(1): 19–25. https://doi.org/10.15391/snsv.2023-1.003
16. Rovniy A, Mulyk K, Perebeynos V, Ananchenko K, Pasko V, Perevoznyk V, Dzhym V. Optimization of judoist training process at a stage of gradual decline of sporting achievements. *Journal of Physical Education and Sport*. 2018;18(4):2447–2453. https://doi.org/10.7752/jpes.2018.04367
17. Farahani J, Soltani P, Rezlescu C, Walsh V. Assessing decision making using 2D animations in elite academy footballers. In: *Progress in Brain Research*, Elsevier; 2020. P. 71–85. https://doi.org/10.1016/bs.pbr.2020.06.016
18. Romanenko V, Piatysotska S, Lytvynenko A, Baibikov M, Boychenko N, Ponomarov V. Methodology for assessing the reaction of combat athletes to a moving object. *Slobozhanskyi Herald of Science and Sport*, 2024;28(2): 69–77. https://doi.org/10.15391/snsv.2024-2.003
19. Romanenko V, Cynarski WJ, Tropin Y, Kovalenko Y, Korobeynikov G, Piatysotska S, et al. Methodology for Assessing Spatial Perception in Martial Arts. *Applied Sciences*, 2025;15(6): 3413. https://doi.org/10.3390/app15063413
20. Korobeynikov GV, Korobeynikova LG, Romanyuk LV, Dakal NA, Danko GV. Relationship of psychophysiological characteristics with different levels of motivation in judo athletes of high qualification. *Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports*, 2017;21(6): 272–278. https://doi.org/10.15561/18189172.2017.0603
21. Romanenko V, Podrigalo L, Cynarski WJ, Rovnaya O, Korobeynikova L, Goloha V, Robak I. A comparative analysis of the short-term memory of martial arts' athletes of different level of sportsmanship. *Ido Movement for Culture. Journal of Martial Arts Anthropology.* 2020;20(3):18–24. https://doi.org/10.14589/ido.20.3.3

22. Beavan A, Chin V, Ryan LM, Spielmann J, Mayer J, Skorski S, et al. A Longitudinal Analysis of the Executive Functions in High-Level Soccer Players. *Journal of Sport & Exercise Psychology*, 2020;42(5): 349–357. https://doi.org/10.1123/jsep.2019-0312
23. Latyshev M, Tropin Y, Podrigalo L, Boychenko N. Analysis of the Relative Age Effect in Elite Wrestlers. *Ido Movement for Culture. Journal of Martial Arts Anthropology*. 2022;22(3):28–32. https://doi.org/10.14589/ido.22.3.5
24. Latyshev M, Tropin Y, Pryimakov O, Curby D, Dokmanac M, Baic M, Korobeynikov G, Kerimov F, Khamidjonov A, Mirzolim M. Greco-Roman Wrestling on the World Stage: Performance Trends and Country Comparisons. *Journal of Martial Arts Anthropology,* 2024;24(4):33–39. https://doi.org/10.14589/ido.24.4.5
25. Stanković N, Todorović D, Milošević N, Mitrović M, Stojiljković N. Aggressiveness in Judokas and Team Athletes: Predictive Value of Personality Traits, Emotional Intelligence and Self-Efficacy. *Frontiers in Psychology*, 2022;12: 824123. https://doi.org/10.3389/fpsyg.2021.824123
26. De Joode T, Tebbes DJJ, Savelsbergh GJP. Game Insight Skills as a Predictor of Talent for Youth Soccer Players. *Frontiers in Sports and Active Living*, 2021;2: 609112. https://doi.org/10.3389/fspor.2020.609112
27. Giordano G, Gómez-López M, Alesi M. Sports, Executive Functions and Academic Performance: A Comparison between Martial Arts, Team Sports, and Sedentary Children. *International Journal of Environmental Research and Public Health*, 2021;18(22): 11745. https://doi.org/10.3390/ijerph182211745
28. Chekroud SR, Gueorguieva R, Zheutlin AB, Paulus M, Krumholz HM, Krystal JH, et al. Association between physical exercise and mental health in 1·2 million individuals in the USA between 2011 and 2015: a cross-sectional study. *The Lancet Psychiatry*, 2018;5(9): 739–746. https://doi.org/10.1016/S2215-0366(18)30227-X
29. Chang ECH, Chu CH, Karageorghis CI, Wang CC, Tsai JHC, Wang YS, et al. Relationship between mode of sport training and general cognitive performance. *Journal of Sport and Health Science*, 2017;6(1): 89–95. https://doi.org/10.1016/j.jshs.2015.07.007
30. Cho SY, So WY, Roh HT. The Effects of Taekwondo Training on Peripheral Neuroplasticity-Related Growth Factors, Cerebral Blood Flow Velocity, and Cognitive Functions in Healthy Children: A Randomized Controlled Trial. *International Journal of Environmental Research and Public Health*, 2017;14(5): 454. https://doi.org/10.3390/ijerph14050454
31. Wang CH, Chang CC, Liang YM, Shih CM, Chiu WS, Tseng P, et al. Open vs. Closed Skill Sports and the Modulation of Inhibitory Control. Sinigaglia C (ed.) *PLoS ONE*, 2013;8(2): e55773. https://doi.org/10.1371/journal.pone.0055773
32. Gu Q, Zou L, Loprinzi PD, Quan M, Huang T. Effects of Open Versus Closed Skill Exercise on Cognitive Function: A Systematic Review. *Frontiers in Psychology*, 2019;10: 1707. https://doi.org/10.3389/fpsyg.2019.01707
33. Di Russo F, Bultrini A, Brunelli S, Delussu AS, Polidori L, Taddei F, et al. Benefits of Sports Participation for Executive Function in Disabled Athletes. *Journal of Neurotrauma*, 2010;27(12): 2309–2319. https://doi.org/10.1089/neu.2010.1501
34. Becker DR, McClelland MM, Geldhof GJ, Gunter KB, MacDonald M. Open-Skilled Sport, Sport Intensity, Executive Function, and Academic Achievement in Grade School Children. *Early Education and Development*, 2018;29(7): 939–955. https://doi.org/10.1080/10409289.2018.1479079
35. Mulert C, Gallinat J, Dorn H, Herrmann WM, Winterer G. The relationship between reaction time, error rate and anterior cingulate cortex activity. *International Journal of Psychophysiology*, 2003;47(2): 175–183. https://doi.org/10.1016/S0167-8760(02)00125-3
36. Eadie R. An overview of contemporary scientific research into the physiological and cognitive benefits of judo practice. *Martial Art Studies*. 2023;14:78–82. https://doi.org/10.18573/mas.160
37. Ward P, Williams AM. Perceptual and Cognitive Skill Development in Soccer: The Multidimensional Nature of Expert Performance. *Journal of Sport and Exercise Psychology*, 2003;25(1): 93–111. https://doi.org/10.1123/jsep.25.1.93
38. Wylie SA, Ally BA, Van Wouwe NC, Neimat JS, Van Den Wildenberg WPM, Bashore TR. Exposing an "Intangible" Cognitive Skill Among Collegiate Football Players: III. Enhanced Reaction Control to Motion. *Frontiers in Sports and Active Living*, 2019;1: 51. https://doi.org/10.3389/fspor.2019.00051
39. Singh AS, Saliasi E, Van Den Berg V, Uijtdewilligen L, De Groot RHM, Jolles J, et al. Effects of physical activity interventions on cognitive and academic performance in children and adolescents: a novel combination of a systematic review and recommendations from an expert panel. *British Journal of Sports Medicine*, 2019;53(10): 640–647. https://doi.org/10.1136/bjsports-2017-098136
40. Muiños M, Ballesteros S. Peripheral vision and perceptual asymmetries in young and older martial arts athletes and nonathletes. *Attention, Perception, & Psychophysics*, 2014;76(8): 2465–2476. https://doi.org/10.3758/s13414-014-0719-y
41. Zwierko T, Osinski W, Lubinski W, Czepita D, Florkiewicz B. Speed of Visual Sensorimotor Processes and Conductivity of Visual Pathway in Volleyball Players. *Journal of Human Kinetics*, 2010;23(2010): 21–27. https://doi.org/10.2478/v10078-010-0003-8
42. Wu Y, Zeng Y, Zhang L, Wang S, Wang D, Tan X, et al. The role of visual perception in action anticipation in basketball athletes. *Neuroscience*, 2013;237: 29–41. https://doi.org/10.1016/j.neuroscience.2013.01.048
43. Supiński J, Kubacki R, Kosa J, Obmiński Z, Moska W. Usefulness of the psychomotor tests for distinguishing the skill levels among older and younger judo athletes. *Archives of Budo*. 2014;10:315–322.
44. Lee JB, Matsumoto T, Othman T, Yamauchi M, Taimura A, Kaneda E, et al. Coactivation of the Flexor Muscles as a Synergist with the Extensors during Ballistic Finger Extension Movement in

Trained Kendo and Karate Athletes. *International Journal of Sports Medicine*, 1999;20(01): 7–11. https://doi.org/10.1055/s-2007-971083
45. Bengtsson SL, Nagy Z, Skare S, Forsman L, Forssberg H, Ullén F. Extensive piano practicing has regionally specific effects on white matter development. *Nature Neuroscience*, 2005;8(9): 1148–1150. https://doi.org/10.1038/nn1516
46. Woods CT, Raynor AJ, Bruce L, McDonald Z. Discriminating talent-identified junior Australian football players using a video decision-making task. *Journal of Sports Sciences*, 2016;34(4): 342–347. https://doi.org/10.1080/02640414.2015.1053512
47. Lemoyne J, Brunelle JF, Huard Pelletier V, Glaude-Roy J, Martini G. Talent Identification in Elite Adolescent Ice Hockey Players: The Discriminant Capacity of Fitness Tests, Skating Performance and Psychological Characteristics. *Sports*, 2022;10(4): 58. https://doi.org/10.3390/sports10040058
48. Till K, Jones BL, Cobley S, Morley D, O'Hara J, Chapman C, et al. Identifying Talent in Youth Sport: A Novel Methodology Using Higher-Dimensional Analysis. Sampaio J (ed.) *PLOS ONE*, 2016;11(5): e0155047. https://doi.org/10.1371/journal.pone.0155047

Information about the authors:

Vyacheslav Romanenko; Phd (Physical Education and Sport), Associate Professor; https://orcid.org/0000-0002-3878-0861; slavaromash@gmail.com; Department of Martial Arts, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

Yrui Tropin; Phd (Physical Education and Sport), Associate Professor; https://orcid.org/0000-0002-6691-2470; tropin.yurij@gmail.com; Department of Martial Arts, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

Leonid Podrigalo; (Corresponding author); Professor; https://orcid.org/0000-0002-7893-524X; leonid.podrigalo@gmail.com; Department of Sport Medicine and Gygiene, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

Natalya Boychenko; Phd (Physical Education and Sport), Associate Professor; https://orcid.org/0000-0003-4821-5900; natalya-meg@ukr.net; Department of Martial Arts, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

Anatoly Abdula; Phd (Physical Education and Sport), Associate Professor; https://orcid.org/0000-0002-3832-3716; anatoliy.ab12@gmail.com; Department of Football and Hockey, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

Nataliia Sereda; Phd (Physical Education and Sport), Associate Professor; https://orcid.org/0000-0002-8320-3000; sereda_nataliya86@ukr.net; Department of Physical Education Management, Kharkiv State Academy of Physical Culture; Kharkiv, Ukraine.

Yaroslav Yatsiv; Phd (Physical Education and Sport), Associate Professor; https://orcid.org/0000-0003-2474-0401; yatsiv64@gmail.com; Faculty of Physical Education and Sports, Vasyl Stefanyk Precarpathian National University; Ivano-Frankivsk, Ukraine.

Cite this article as:

Romanenko V, Tropin Y, Podrigalo L, Boychenko N, Abdula A, Sereda N, Yatsiv Y. Specific features of cognitive skill development in athletes of situational sports. *Pedagogy of Physical Culture and Sports,* 2025;29(3):194–203.
https://doi.org/10.15561/26649837.2025.0305

Received: 18.04.2025
Accepted: 05.06.2025; Published: 30.06.2025