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Original Article

Reaction speed and attention of elite youth soccer goalkeepers: Do cognition and reaction influence each other?

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Abstract
Problem Statement: Do cognition and reaction influence each other? Purpose: This research examined the level of cognitive performance and the interconnection with the disjunctive reaction speed in elite youth soccer goalkeepers. Soccer goalkeepers often need to have focused attention and a fast reaction when dealing with short-term problem-solving situations. In the research discussed in this article, we separately investigate the reaction speed to various stimuli and results of online cognitive tests. Research has only recently begun to focus on cognitive abilities of goalkeepers. The study involved 31 participants (184.8 ±4.7 cm; 77.6 ±7.1 kg) from elite Slovakian soccer academies selected from three youth categories: U16, U17, and U19. In this study, the level of disjunctive reaction abilities was measured using two tests: the response to the fast-generating visual stimuli (FGS) test and the response to the slow-generating visual stimuli (SGS) test. To evaluate the level of cognitive abilities, the Stroop test and the Attention test were used. The normative data as percentile ranges were highlighted in the selected test parameters. The significance level was established at $p < 0.05$. Results: The research has revealed that the ability of the players to react to SGS was correlated with the performance in the FGS test ($r = 0.55$ [CI 95; 0.24–0.76], $p < 0.001$). A significant correlation was found between performance in the Attention and Stroop tests ($r = 0.58$ [0.29–0.78]; $p < 0.001$). Conclusions: Low levels of correlation among reaction and cognitive tests revealed that reaction and cognition do not influence each other for soccer goalkeepers. Therefore, reaction and cognition should play a separate role in the testing of soccer goalkeepers.
Key Words: evaluation, executive functions, response time, talent identification, soccer.

Introduction

Perceptual and cognitive skills are considered essential in high levels of invasive team sports (Scharfen & Memmert, 2021). In challenging decision-making scenarios characterized by environmental congestion, the simultaneous incorporation of vast visual information can be viewed as an indicator of exceptionally skilled players (Mann et al., 2007). In addition to the superior physical fitness of elite athletes, it is proposed that assessing factors such as reaction time and perceptual-cognitive functions may distinguish athletes between different levels (Huijgen et al., 2015; Murr et al., 2018; Obetko et al., 2020; Trajkovic & Bogataj, 2020). This concept applies to talent identification processes in numerous team sports.

Soccer players dedicate themselves to their assigned positions on the field. The playing position determines the physical and technical-tactical requirements of players (Di Salvo et al., 2007). Goalkeepers (GKs) are assigned a unique position. Their physical fitness and technical skills are typically worse than those of players in other positions on the field (Joo & Seo, 2016), so that West (2018) in accordance with the FIFA and Vencel (n.d.) determines for younger GKs more work on fundamental techniques such as footwork and movements towards the ball, catching shots around the body, fall and diving techniques. Liu, Goméz & Lago-Peñas (2015) recognized that goalkeeper is the most specialized position on a soccer team and is regarded as a factor in the final outcome of the match. Goalkeepers are frequently involved in decision-making situations that require attention to enable them to choose and concentrate on relevant stimuli and respond adequately as soon as possible based on their reaction speed. According to Peiyong & Inomata (2012), goalkeepers point to a better reaction time to predict the kick direction when compared with other players from another field position. In 2019, a new rule for penalty feet positioning (to have only one foot or part of it on the goal line when the kicker

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hits the ball instead of both feet on the line) was applied in soccer (Monteiro et al. 2022). The research of these authors showed that goalkeepers dive further ($p<0.001$) and faster ($p<0.001$) according to the new rule. Villemain & Hauw (2014) considered attention and presence to be the important psychological skills needed for GKs. Currently, these indications are easily recognized by modern, accessible, and well-investigated methods. Reaction speed and cognitive functions are often undervalued. Savelsbergh et al. (2002) showed that expert GKs possess superior visual search and anticipation skills when compared with novice players. Expert GKs place higher demands on their particular qualities and skills, which helps the team prevent the opponent from scoring. These skills are based on the neuromuscular and cognitive functions of GKs. Shorter reaction time to visual cues, rapid decision-making, and the ability to maintain focus throughout the match are essential for great GKs. Research supports the idea that superior GKs depend on reaction rather than anticipation while defending against a shot at goal (Navia et al., 2018). Therefore, it is beneficial to understand the interconnection between the reaction speed and the cognitive functions of soccer GKs.

According to Otte et al. (2019), four skill sets are considered essential by goalkeeper coaches; these are decision-making skills, athleticism, mentality, and technical skills. Specific training of GKs should integrate technical skills and perceptual-cognitive components that integrate decision-making. GKs are significantly faster in response-initiation time than field players in soccer, which indicates their superior need for a quick reaction time and a high level of executive functioning (Peiyong & Inomata, 2012). Another study suggests that GKs can be evaluated on the level of their attentional skills or focus (Shimi et al., 2021). Rueda et al. (2021) in their article argued that paying attention consists of tuning the mind with the environment in a conscious and controlled mode that enables strategic and flexible adaptation to responses analogously to internal motivations and goals.

However, these aspects of their performance are often neglected by practitioners in the selection of talented GKs. Kalén et al. (2021) research did not yield enough evidence to support the idea that cognitive functions and skills can predict future sports performance. They did not find any evidence to support claims that practitioners should use tests of general cognitive functions, such as executive functioning, for the identification of talent or player selection.

Reaction time variables are used widely in studies of human cognitive performance and neuropsychological testing (Deary, & Der, 2005; Kallus, Schmitt, & Benton, 2005; Kumar et al., 2020; Nucci et al., 2023) because reaction time and speed of reaction to various stimuli have been associated with cognitive processes. More research is required to determine how well highly talented soccer players develop general perceptual-cognitive abilities and position-specific differences, as suggested by Schumacher et al. (2018). So, we decided to examine the cognitive processes that impact soccer players' performance, such as reaction speed and attention, especially in goalkeepers.

Consequently, the lack of available testing methods and transparent testing data leads us to reveal the level of reaction speed and cognitive performance of soccer GKs. The purpose of the research is to evaluate selected research data collected from GKs between the ages of 16 and 19 of the Slovakian soccer academies. This sample may represent the elite youth GKs population, which makes these data unique. These possible findings will pinpoint the interconnection between reaction speed and cognitive functions of soccer GKs. The normative data of elite players can provide a starting point for reaction speed and cognitive testing in soccer academies that aim to identify the strengths and weaknesses of soccer GKs.

Materials and methods

The purpose of the research was to investigate the level and relationship between the reaction speed and cognitive functions of the elite youth soccer GKs. The design of the cross-sectional study was implemented. The main method of data acquisition was sensorimotor testing of reaction speed and assessment of computer-based cognitive functions.

Participants

The research group consisted of 31 elite youth GKs (184.8 ±4.7 cm; 77.6 ±7.1 kg) of four elite soccer academies in Slovakia. These GKs were hired from categories U16, U17, and U19. Each subject and his parents consented to participate in the experiment and were informed of his right to withdraw from the study at any time. The research was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Physical Education and Sports (no. 8/24).

Procedures

Reaction Speed Tests

For both tests, 4 sensors of the SportReact system (SportReact, Zagreb, Croatia) placed side by side on a table at distances of 10 cm from the outer edges were used. Before actual testing, three protocols were created where 20 stimuli were set up equally between these sensors, that is, each contained five correct responses. The task of the test subjects was to respond as quickly as possible to the corresponding stimulus by waving in front of the sensor display. Subjects were instructed to use both upper limbs (left hand on two left side sensors; right

hand on two right side sensors) and, after marking the response, to use them to move back to the starting position in the middle of these four sensors. The time taken for data collection was the best in all three trials.

When responding to fast-generating visual stimuli (FGS), the subject responded only to green LED lights. The other sensor appeared to be different in color or did not light up at all. The stimulus generation rate was instantaneous, meaning that as soon as one marked the correct photocell, the other photocell immediately lit up again.

When responding to slowly generating visual stimuli (SGS), the subject responded in the same way as in the previous case, but the stimuli were generated with a time delay of one second after marking the correct sensors. Material equipment required for these procedures were the following: SportReact system (SportReact, Zagreb, Croatia), measuring tape, table.

Cognitive Function Tests

To evaluate the level of cognitive and attentional abilities, we used the Stroop test and the Attention test. Both were for online use (I-Psychologia, 2025; Eduself.sk, 2025). We use the computerized tests, WIN-6 CCT; this is a 5x5 numeric attention test and the computerized Stroop test of cognitive ability.

Attention test

The WIN-6 CCT test is called the numeric square or Schulte table test. Numbers 1 to 25 are randomly placed in a square matrix with five rows and five columns after starting the test. The participant had to find and sequentially select the numbers in the matrix in ascending order, starting with the lowest number and ending with the highest number, and should click on the number in ascending order from 1 to 25 as quickly as possible. The test was repeated 10 times. When the test started, the time to calculate was started. If there was a mistake (e.g. the number out of order), the time kept running with the warning on what number had to be clicked. The final time determined the level of attention to: very attentive type (<35.000 seconds), attentive type (<35.001 and <40.000 seconds), slightly attentive type (<40.001 and <45.000 seconds), average attentive type (<45.000 and <50.000 seconds), slightly inattentive type (<50.001 and <55.000 seconds), inattentive type (<55.001 and <60.000 seconds), and very inattentive type (<60.001). The Schulte Table test is considered one of the most efficient training methods to improve peripheral vision, attention, and memory.

Stroop test (modified)

For the study of interference effects on attention, the Stroop test was developed (Stroop, 1935). The participant is instructed to name the color of a word presented while ignoring the meaning of the word. The original Stroop test is a brain training test in which words are written in different colors and the reader's task is to read these words according to the color in which they are written. Nowadays, the Stroop test is also available as a computerized version. The advantages are the consistency of the secure administration by computer programming and the fact that the scoring is displayed immediately after finishing the test. There is no delay in milliseconds as when it was measured by the administrator (delayed by his own reaction time of clicking the button when the task was at the end). The Stroop test focused on the ability to work simultaneously with two modes of perception: visual perception processing (text color) and the second, text comprehension. We used the modified version of the computerized version for self-evaluation (Eduself.sk., 2025). The task consists of a text (a word name for a color), and this word is colored with a certain color (it can also be the same color as the text). The task is to mark the color that corresponds to the color of the word. Example: If the word green is written in red, the participant should select the option red (small rectangle in red). Before starting the test, we tested participants with two color blindness tests. The Stroop test was repeated ten times, and all the attempts were registered with this characteristic: time, correct, incorrect attempts of selected colored rectangles.

Statistical analysis

The normality distribution of the collected data was established by the Shapiro-Wilk test. Descriptive analysis of the results includes standard deviation of the mean (SD), standard error of the mean (SEM), 95% confidence interval (95% CI), and coefficient of variation (CV). We report the normative data as percentile ranges. We employed correlation and simple linear regression analysis to determine the level of association and prediction of the dependent variable from the independent variables. The coefficient of determination (R^2), calculated as the square of r, was adopted to demonstrate the extent to which the whole variation in the dependent variable can be clarified by the independent variable. The correlation was explained as trivial ($r < 0.1$), small ($0.1 \leq r < 0.3$), moderate ($0.3 \leq r < 0.5$), large ($0.5 \leq r < 0.7$), very large ($0.7 \leq r < 0.9$), and perfect ($0.9 \leq r < 1$) (Hopkins, 2006). The significance level was established at $p < 0.05$. Statistical analyses were performed with GraphPad Prism v10.3.1 (GraphPad Software, San Diego, CA, USA).

Results

Normative data for reactions and cognitive test results

The descriptive data for the reaction and cognitive performance of elite youth soccer GKs are highlighted in Table 1.

Table 1. Descriptive data and the normative distribution of the reaction and cognitive performance of elite youth soccer GKs (n = 31)

						Percentile				
	M	*SD*	*SEM*	*95% CI*	*CV (%)*	*10th*	*25th*	*50th*	*75th*	*90th*
FGS [s]	25.40	0.33	0.06	25.3, 25.5	1.3	25	25.2	25.4	25.7	25.9
SGS [s]	8.65	0.45	0.08	8.49, 8.81	5.2	8.03	8.24	8.6	9.01	9.29
Attention test [s]	34.70	6.48	1.16	32.4, 37.1	18.6	26	29	34.7	39.2	43.5
Stroop test [s]	14.60	1.43	0.26	14.1, 15.2	9.7	13.1	13.5	14.4	15.9	16.7

Notes: M ±SD: mean ± standard deviation, SEM: standard error of the mean, 95% CI: 95% confidence interval, CV = coefficient of variation.

Attention test

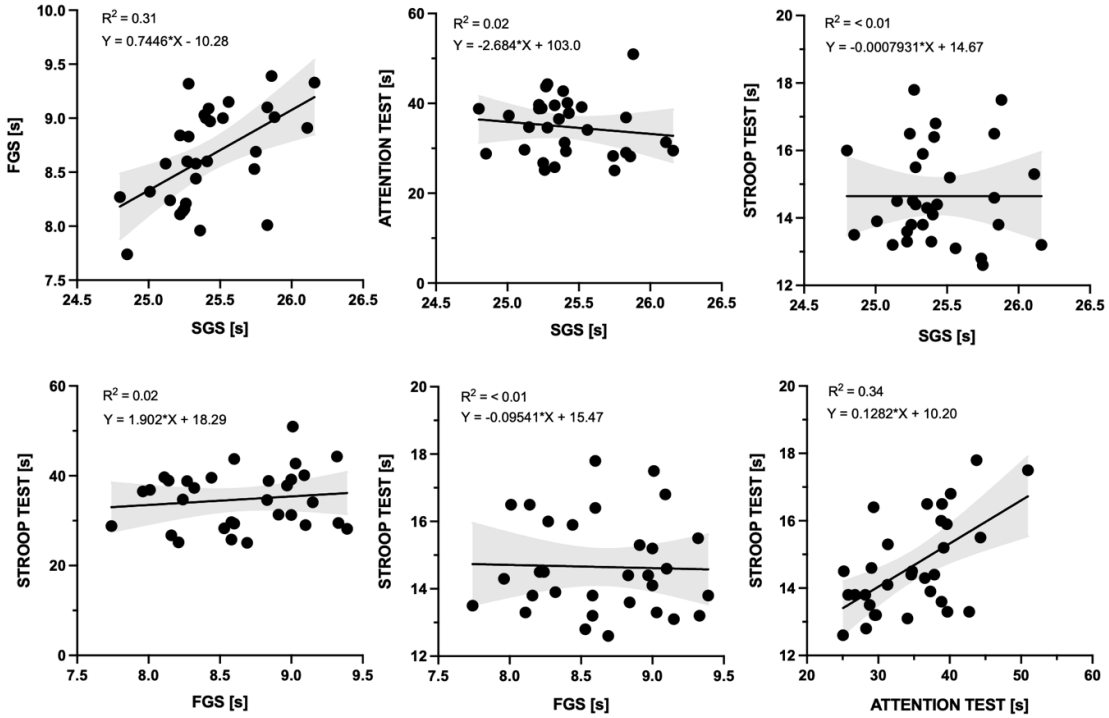
Attention determination shows that young goalkeepers whose mean time to accomplish the task was 34.7 ±6.4 seconds belong to the very attentive type of people group, to which only 9.8% of the total of 988 987 people who took this online test belong.

Modified Stroop test

The mean time in youth soccer GKs for this modified Stroop test was 14.6 ±1.43. The best recorded time for a general population user taking this online test was 10 seconds. Our similar study (not yet published) without differentiation of player functions in the field showed that fifty 21-year-old male footballers achieved a time of 15.39±2,84 seconds, which is a worse time compared to the measured U16-19 GKs.

Associations between reaction and cognition tests

The ability of the players to react to the SGS test was correlated with the performance on the FGS test (r = 0.55 [CI 95; 0.24–0.76], p < 0.001), while it was not associated with attention (r = -0.14 [CI 95; -0.67–0.23]) or their Stroop test performance (r < 0.01). Performance in reactions to FGS was not associated with attention (r = 0.14 [-0.23–0.46]) nor with the performance of the Stroop test (r = -0.03 [-0.38–0.33]). A significant correlation was found between the performance on the Attention and Stroop tests (r = 0.58 [0.29–0.78]; p < 0.001). Figure 1 shows the regression analyses among the reaction and cognitive performance parameters.



Notes: Black dots represent data from each participant, black line represents a regression curve, gray area represents the 95% CI band, R^2: coefficient of determination.

Figure 1 Linear regression analysis between reaction and cognitive test parameters

Discussion

Since disjunctive reaction time can be considered a selection criterion for soccer GKs (Obetko et al., 2019), our study presents the normative data for novel choice reaction speed tests that practitioners can use for their selection in the categories U16, U17, and U19 in first-tier soccer academies. Our results also showed that the ability of GKs to respond to slowly and rapidly generated visual stimuli (SGS and FGS) was significantly correlated, suggesting common perceptual and response mechanisms. This was true for the two cognitive function tests selected for the purposes of our study. The level of attention measured by the Stroop task and the Attention task indicates that these tests might be useful tools for the assessment of deeper perceptual-cognitive processes of elite GKs.

The results showed that goalkeepers' ability to respond to slowly and rapidly generated visual stimuli (SGS and FGS) correlated, suggesting common perceptual and response mechanisms. This is in line with a study by Piechota, & Majorczyk (2023), who emphasize the importance of neuromuscular coordination and movement economy in dynamic activities such as GKs defensive game activities. The fact that performance in reaction tests was not significantly related to cognitive tests like the Stroop test or the Attention test suggests that these factors are controlled by separate cognitive motor pathways.

Knoop et al. (2013) also found that significant differences were observed between the main GKs and their substitutes, particularly in the comprehensive RAS (reaction and action speed) tests. The main GKs performed better, confirming the construct validity of these tests and their ability to discriminate between performance levels. This difference can be attributed to the difficulty of complex tests that require the integration of perceptual and motor components, which better reflects the real performance demands of soccer GKs.

Piechota, & Majorczyk (2023) stated that older, more experienced GKs exhibited better motor control parameters, muscle activation, and movement patterns that influence the economy of physical effort. These findings may have important implications for planning the training process for soccer GKs. Experienced GKs achieved significantly shorter decision-making time (250-260 ms; $p = 0.001$) during saving actions after the kicker's shot at the goal than youth-novices GKs (300-320 ms). The Electromyography (EMG) of the structure of the movement pattern affected the effort economy and eye-muscle coordination from the moment the attacker took the shot until the completion of the saving action by the goalkeeper.

In addition, the fact that there was a significant correlation between Stroop test scores and Attention test scores may support the idea that these mental abilities are related and help to improve psychomotor performance. This is consistent with research suggesting a role for inhibitory control and sustained attention in complex motor tasks (Piechota, & Majorczyk, 2023).

The level of cognitive functions measured by the Stroop test and the Attention tests has shown a large correlation ($r = 0.58$). This is in agreement with Horička et al. (2020) who found the significant relationship between performance on the reactive agility test and intelligence test ($r = 0.67$) in adolescent athletes. Although this study was not exclusively dedicated to soccer GKs, a similar trend in the sporting population indicates that a more thorough analysis would be needed to analyse the cognitive domains that are the most related to soccer performance. As James (1890) wrote that attention is the constant stream of sensory information and, in parallel, a decision for the appropriateness and timing of responses, and these are very important and crucial abilities of the human organism, and we are adding that especially in a quick sport game like soccer. The act of paying attention implies a degree of reactive spontaneity. In general, the findings of Shimi et al. (2021) confirm that cognitive skills related to attention play a critical role in the efficient execution of soccer-specific tasks. These findings have important implications for the training of cognitive skills in sports. The results of Vaughan & Laborde (2021) provide an explanation of how attention interacts to predict sports performance, and that is why diagnostics of attention in goalkeepers creates an important part of the training process.

According to Štulrajter, Peráček, & Ramacsay (1986), football and speed are a good combination. Athletes rely heavily on fast reactions because quick responses can take advantage in solving sports situations and direct to winning the game, race and competition. Supradi et al. (2023) demonstrated that using a ball launcher that threw a ball with a specified speed, but a non predicted direction could improve reaction speed of the goalkeeper. Zhang (2023) explored the relationship between athlete´s reaction time and different training methods and concluded that different training methods can improve athletes´ competitive level and reaction speed.

Consequently, our study has some limitations. First, the number of subjects is smaller than expected for the normative data distribution. However, GKs are in the unique position in soccer where only two to three of them are included in the squad of each team. Furthermore, we used disjunctive reaction tests, of which validity and reliability are not yet thoroughly evaluated.

These results underscore the importance of a well-focused training intervention that integrates cognitive function, reaction abilities, and neuromuscular coordination. Together, these factors contribute significantly to improving sports performance. Taking these aspects into account in training programs can not only improve the performance of soccer GKs but also reduce the risk of injury (Dansu, Okuneye, & Idowu, 2017; Wilkerson, Simpson, & Clark, 2017). Our recommendations agree with Moreno-Pérez et al. (2020) that overall coaches

should consider the positional demands of goalkeepers, and the differing performance needs of goalkeepers to better optimise training outcomes for these players.

Further research could investigate the interaction between these abilities at different load levels and in specific game situations.

Conclusions

The goalkeepers of elite youth soccer perform in a cognitively demanding environment. This study provided available methods to evaluate their reaction and cognitive performance. Additionally, the distribution of normative data in our study shows the level of reactive and cognitive performance in the sample of elite academy GKs, which they can use to compare.

Second, reaction and cognition do not interrelate for soccer GKs. The low-level correlation between reaction and cognitive tests revealed this.

However, the reaction to fast- and slow-generating light stimuli correlates significantly and it can be said that they influence each other. The correlation between attention on the WIN-6 CCT test and cognition on the Stroop test is significant, and it can also be concluded that they influence each other.

Therefore, reaction and cognition should play a separate role in the testing procedures for soccer GKs.

Conflicts of interest

The authors declare that they have no conflict of interest.

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