

# **The short-term effects of cognitive preparation on different motor and cognitive skills in youth male football players**

## **1. Introduction**

Football is a sport to make quick decisions, find free spaces and new positions, and create new possibilities. Football players need to efficiently and quickly extract meaningful information through flexible visual search strategies and short periods of fixation on informative visual cues (Casella, 2022), plan the most appropriate plan of action, and anticipate the actions of their opponents (Vestberg et al., 2012). Players change environments rapidly, and they plan their future actions by perceiving the simultaneous actions of their teammates and opponents. In football, the game's fast pace means players often make decisions and act almost instinctively, without consciously thinking through each move. This complex task requires a broad spectrum of cognitive processes.

A higher level of cognitive functions (CF) in the case of football players is essential in terms of success. CF consists of a wide range of mental deeds such as attention, perception, visual and spatial processing, memory, and executive functions (EF) which refer to a group of neurocognitive skills that contribute to consciously managing our thoughts, actions, and emotions. These skills are fundamental for thoughtful decision-making, purposeful behavior, managing emotions, and navigating complex social situations. They also play a key role in helping to learn independently and adapt to new or changing environments (Casella, 2022), as well as controlling lower-level cognitive processes which include decision-making, working memory, multitasking (Lorenzo Calvo et al., 2021), updating, shifting, inhibition (Zhang, 2023) and cognitive flexibility (Diamond, 2013). These abilities help to execute proper physical actions in a short period of time which refers to reaction time. It determines how quick and efficient a response to a stimulus and initiates a coordinated movement. For example, in sports, having a fast reaction time allows an athlete to quickly respond to a moving ball or an opponent's actions, which is crucial for executing coordinated skills effectively. The speed of a player's reaction directly impacts how quickly they can execute movements in response to game signals or changes. Besides physical performance one of the most critical factors for athletes to respond rapidly to environmental changes. This ability is essential for showcasing technical and tactical skills, gaining an advantage and scoring (Paško et al., 2021). At some points, the performance level of football players is ascertained by the ability to react in unexpected situations and anticipate the movements of the opponent (Vestberg et al., 2012).

EF plays a key role in football, as research proves that higher EF is directly related to the number of goals and assists in football players. A research indicates that EF can be improved through both physical activities like aerobic exercises and cognitive training such as calculation tasks. However, according to their data, combining these activities in motor-cognitive dual-task interventions might be more efficient, as it recruits more mental resources in young male athletes. The dual-task, which included aerobic exercise on a stationary bicycle while performing cognitive tasks like the Stroop test for 30 minutes, enhanced shifting ability and working memory (Zhang, 2023). Another research further investigated the impact of combining physical and cognitive activities on shooting athletes and found significant improvements in their EF. According to the results, combining physical and cognitive training offers greater benefits for EF performance and brain oxygenation in adolescent athletes compared to cognitive training alone (Xiang et al., 2023). Cognitive changes induced by cognitive training are completely different from those induced by physical training. Researchers combined physical and cognitive exercises in order to improve the positive influences of physical activity on people's cognition skills. After cognitive exercises they found a cognitive improvement that might have a relationship with changes in brain structure and function, as reflected by increased cortical thickness and gray matter volume and improved structural and functional connectivity and neural activity, while after physical activity the cognition level is getting affected by changes of molecular activity which is related to synaptic and energy metabolism (Xiang et al., 2023). One study found a strong relationship between cognitive function improvement and physical activity (Symons, 2023), while another highlighted the interaction between cognitive functions and motor skills impacts the growth of brain networks at a functional and structural level (Leisman, 2016).

## **2. Aim of the study**

Regarding these information, we can conclude that CF performance is as vital component of football (Walton et al., 2018) as physical performance (Sabarit et al., 2020), yet the number of related research is very small. Football itself causes cognitive skills to improve (Alesi et al., 2015), however, there is a lack of scientific studies on how to improve the cognitive abilities of children who play football (Alesi et al., 2015) and there is a need to study targeted cognitive training in this sport (Habekost, 2024). Considering that 10-year-old children are undergoing the natural biological maturation of EF, adding cognitive-motor training into this age group can positively influence this process and sports performance. Training and developing EF skills is most effective during

childhood, because key brain areas, like the prefrontal cortex and limbic system, are rapidly developing during this time, laying the foundation for executive functions to emerge (Blair, 2017).

Additionally, there is a greater amount of research on the long-term effects of cognitive training compared to the short-term effects. Warm-up might be one of the ways because it is a significant factor in all sports as well as football. It makes players able to improve and activate their EF level (Leisman, 2016). Including cognitive tasks in the warm-up routine might cause an improvement in cognitive skills in football players. Although warm-up is greatly unknown in terms of cognitive effects.

Another problem is that the majority of studies are laboratory-based instead of investigating cognitive function, based on real-life football skills, to measure the impacts on real football situations. A research explored the effects of two different warm-up protocols. The integrated warm-up protocol was a small-sided 5 versus 5 game in a small space and the analytical warm-up protocol consisted of twelve dynamic football-specific exercises. There was a significant difference between groups, where the integrated warm-up protocol group generated greater technical-decisional performance measured through the Loughborough soccer passing test (LSPT) (Villaseca-Vicuña et al., 2024). Exercises that include football-specific drills such as running, dribbling, passing, and shooting are suggested. These drills require various cognitive and motor skills and play a key role in team success through scoring goals (Konefał et al., 2024; Duncan et al., 2022; Spencer et al., 2019; Phatak and Gruber, 2019; Loutfi et al., 2023).

The research methodologies also ignore conditions, specific to games, where players' actions are influenced by visual and verbal information. Receiving more than 90% of information through visual and auditory channels makes them play a key role in the cognitive process (He et al., 2023). Before taking action, players need to continuously assess the situation, primarily relying on visual perception and other sensory modalities such as audition (Habekost, 2024). Visual search helps athletes gather information about their surroundings, enabling them to predict and read the game. Enhancing this ability can improve an athlete's anticipation, decision-making, and reaction. Furthermore, there is a strong relationship between average pass completion rate and visual exploration frequency (Phatak and Gruber, 2019), but the effect of training with visual stimulation still needs to be more explored. The effect of auditory signals on athletes' performance and their potential use in training has been a subject of interest for researchers in recent years. Studies have shown that athletes can distinguish between their hurdling movements and those of their opponents

using auditory cues. They can also extract audible information produced by themselves or their opponents to recognize changes in their surroundings and anticipate the future movements of their opponents (Schaffert et al., 2019). A study compared the reaction time of two groups of swimmers after four weeks of training. One group underwent regular swimming training, while the other group included auditory signals in their training. The study concluded that the group with auditory stimuli had significantly better reaction times. These data indicate that auditory-motor coupling signals produced in training significantly influence athlete's motor responses. The neuronal stimuli are related to an individual's experience and the adaptable and sensory-cognitive skills of athletes are specific to their sports domain (Papic et al., 2019). There is also a difference between the time that each of these stimuli reaches the brain. There are different sensory modalities and human responses to various stimuli and responses. It is highlighted that the mean auditory reaction time is 140-160ms while the visual reaction time is 180-200. Many studies proved that responding to an auditory stimulus is faster than a response to a visual stimulus and it might be due to the reason that it only takes 8-10ms for an auditory stimulus to reach the brain while for a visual stimulus, it is 20-40ms (Ghuntla et al., 2014).

According to the previous information, including appropriate cognitive drills in warm-up may enhance numerous positive skills in players to have a better mental readiness and perception to perform their best. This study aims to investigate the short-term effects of cognitive preparation through different football-specific motor-cognitive warm-up protocols on motor and cognitive skills in youth male football players.

## **Hypothesis**

Based on our previous research, we made the following hypotheses.

**H1:** Motor-verbal and the motor-visual group will perform at a higher level in the Stroop test, Illinois ball test, and Loughborough soccer passing test compared to the motor group.

**H2:** Motor-visual group will perform at a higher level in the Stroop test, Illinois ball included test, and Loughborough test compared to the motor and motor-verbal group.

**H3:** There will not be difference in T-test performance between any of the groups.

## **3. Method and materials**

### **Participants**

Twenty-four male (n=24) youth football players (age =  $8.0 \pm 0.0$  years, weight =  $30.08 \pm 4.76$  kg, height =  $133.10 \pm 4.66$  cm, BMI =  $16.85 \pm 1.77$ ) were recruited with the permission of their parents who signed an informed convention allowing their children to participate in this research. Participants with current injuries or recent experience of any type of injury or having any special skills were excluded from the research, and the rest of the players were free of any kind of injury or illness. The players had been playing football for 2 years constantly in the same team together with the same training plans. According to their age, they didn't have specific football positions, they played in different positions in each match or training. Parents, players, and their club received an information sheet notifying them that players could withdraw from the test if they experienced any discomfort. The research was conducted at the PVSZ sports complex on a natural grass pitch in Pécs, Hungary.

### **Experimental protocol**

Participants were randomly divided into three groups. After the interventions, the effects of the different warm-up protocols were measured by the Stroop color-world test, Loughborough soccer passing test, Illinois ball test, and T-test, which were the same for all 3 groups. There was a familiarization session before all the tests for players to make them aware of the research procedure. Each participant performed the tests immediately, without having rest after finishing the warm-up exercises. The order and instructions for the tests were described to participants by the examiner before they were performed. The same examiner and helpers were used to eliminate inter-experimenter variability.

### **Stroop color-word test (SCWT)**

SCWT is considered one of the most standard computerized tests for measuring many cognitive mechanisms (Periáñez et al., 2021). It is used to assess executive functions, requiring participants to inhibit their normal response in order to react to an unexpected choice (Ktaiche, 2022). It can measure the inhibition function (Takahashi and Grove, 2020), working memory (Xiang et al., 2023), attention, and cognitive flexibility (Scarpina and Tagini, 2017). Incongruent stimuli demand more neural effort to process, as the brain works to manage the conflict (Huang et al., 2024). Therefore, this study exclusively used the incongruent version to more efficiently measure inhibition function. This version, consisting of ten questions, included the condition of “color naming interference”, where color names in Hungarian were presented in different colors.

For example, the word “red” appeared on the screen, but it was colored blue. The participant had to choose the correct blue color from the three options and press the appropriate button on the test panel as quickly as possible. They have to inhibit reading the word and respond only to its color, leading to a longer response time. This phenomenon is called the “Stroop effect”, which activates brain regions such as the prefrontal cortex (Takahashi and Grove, 2020). In SCWT, the participant’s performance was evaluated based on the time to complete the test in seconds as well as the number of errors made as a percentage of the maximum achievable scores. (Figure 1)

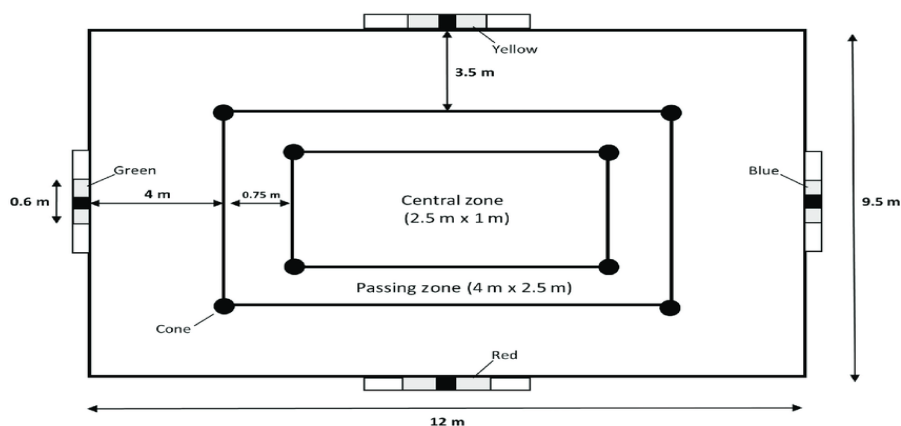


**Figure 1** The representation of the Stroop color-word test with incongruent stimuli.

### **Loughborough soccer passing test (LSPT)**

LSPT is a football-specific performance measurement and standardized test used to assess football players' passing, agility, ball control, and decision-making (Friebe et al., 2024; Villaseca-Vicuña et al., 2024). This test has a central zone where the participant with the ball must stand. Surrounding this central zone is a passing zone, from which the participant needs to pass the ball to determined targets. Four targets are around the passing zone, each of a different color. As soon as the test started the examiner was telling a color according to the same sequence. From sixteen passes eight of them were shorter passes (to yellow and red targets) and the other eight passes were longer (to green and blue targets). The participants in the center had to respond to that audible signal and pass the ball to the determined target from the passing zone, as soon as possible the ball bounced back to the participant, and the examiner immediately called for another pass by telling another color. The participant had to complete sixteen passes as quickly as possible, with their performance evaluated based on the test's finishing time. Penalty time was added to the total performance time if they missed the target (passing above or next to the target) for three seconds, passed to the wrong target for five seconds, touched any cone with the ball, or passed from outside

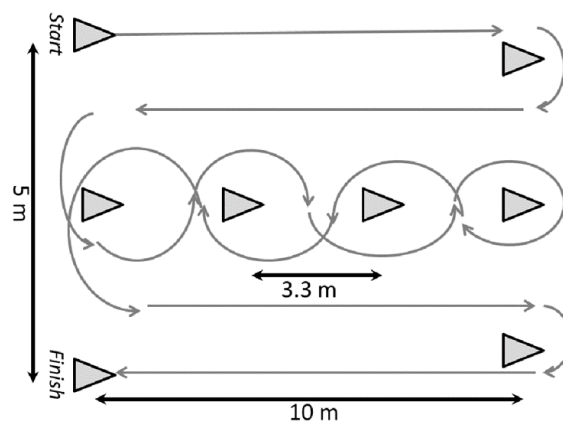
of the passing zone for two seconds, and one second penalty time for every second spent longer than the original test completion time which was forty-three seconds. (Figure 2)



**Figure 2** The schematic picture of the field to LSPT test.

### Illinois ball test (IBT)

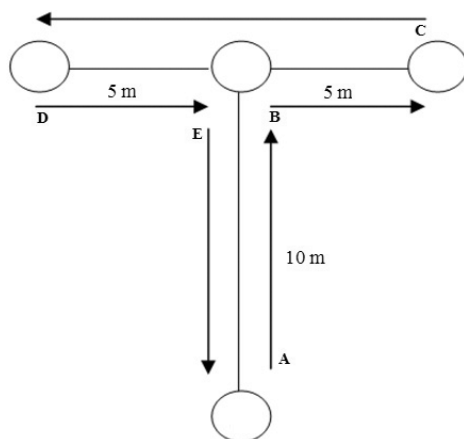
The IBT is one of the most effective tests for assessing football players' agility. It involves sprinting, turning, and weaving through a course marked by cones arranged in a specific pattern. Including the ball in the Illinois test helps assess players' change of direction ability and slalom dribbling at different angles. This method has demonstrated excellent validity for youth football players (Makhlouf et al., 2022). During the test, participants stand behind the starting point with the ball, and upon hearing the sound of the whistle, begin performing it. The total time to complete the course is recorded in seconds and the number of fails was considered when players couldn't dribble the obstacles and if they forgot the order as well as dropping the cones. (Figure 3)



**Figure 3** The Schematic representation of the Illinois ball test.

## T-test

The T-test, a valid measure of sprinting speed, lower-body strength, and agility in athletes (Raya et al., 2013), was used in our study to assess participants' agility without a ball. It is a four-directional test requiring players to maintain balance, change direction rapidly and prevent loss of speed (França et al., 2022). Participants stand behind the starting point. Upon hearing the sound of the whistle, they sprint toward the central cone, shuffle to the left cone, quickly shift to the right cone, then return to the central cone, and finally run backward to the starting point to complete the test. (Habekost, 2024). Performance was measured based on the finishing time of the test by seconds. (Figure 4)



**Figure 4** The schematic picture of the T-test.

### Warm up protocol

Recognizing the significance of visual and auditory signals in sports, we decided to supplement the motor tasks with verbal instruction in one group to measure their cognitive function based on the auditory collective information, which allowed us to analyze the impact of auditory signals on their motor-cognitive functions. In another group, we incorporated visual stimulation signals into the motor exercises to assess how perceived visual information influenced their motor-cognitive performance. The players were divided into three equal groups of eight: the motor-verbal (MVEG), the motor-visual (MVIG), and the motor group (MG). We incorporated specific cognitive tasks into the players' pre-training warm-up. While the tasks were identical across the three groups, the source of information on how to execute them differed. MG received complete instructions about each task beforehand, details on the task itself and the order and sides of the runs, passes, and shoots. In contrast, MVEG and MVIG were informed about the tasks but received additional instructions on the order and sides of the runs, passes, and shoots only during the drills. For MVEG, this was done verbally by the examiner saying “left” or “right”, “red” or “green”. For

MVIG, visual cues were provided through cards with different colors or hand signs (left or right) by the examiner. Each task lasted for two minutes, except for the running exercise, which lasted for one minute per participant.

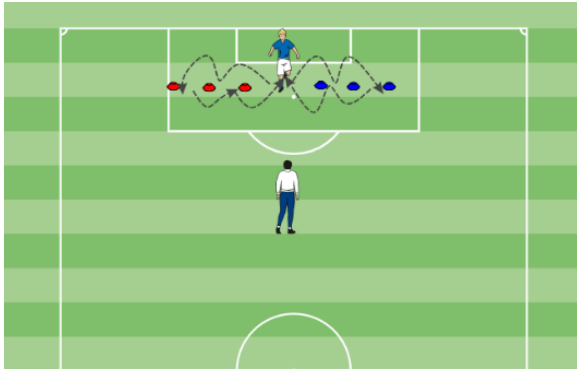
In the running exercise, participants shuffled laterally between cones placed on their left and right, returning to the center after reaching the side cone. MG got all the information in advance from the examiner before starting the task, so they knew to start to shuffle to the right side and then come back to the center, then to the left. They continued the task in the same order for one minute. For MVEG the participants were responding to verbal orders from the examiner (left and right), and then they had to shuffle in the direction the examiner ordered. For MVIG the examiner was showing the direction with hand signs by pointing at the direction (left and right) where they had to shuffle. (Figure 5)

In the shooting exercise, a participant and a helper were passing constantly to each other and then in a determined time, the participant had to touch the ball and carry the ball outside of his zone and then shoot first to the right goal and then next time to the left one, then continuing in the same order. MG had all the information in advance, and they had to start the shooting part after ten passes, while MVEG had to respond to the examiner's verbal order "RIGHT or LEFT" in order to initiate the second part of the exercises which was shooting. For MVIG examiner showed a green or white card, and then they had to carry the ball outside of the zone and shoot to the proper goal. (Figure 6)

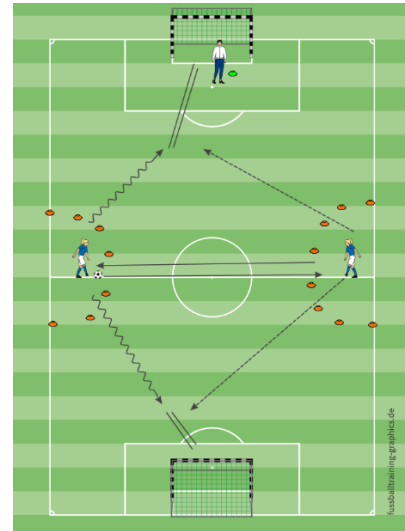
In the passing exercise, there were 4 helpers positioned around the center between colored cones and the participant in the center holding the ball. The participant had to pass to the side helpers and receive the ball back. The MG received instructions on the passing sequence in advance (clockwise direction). For the MVEG, the examiner called out the color of the cone to indicate the target (blue, red, yellow, or green), and the participant in the center passed to the helpers standing between the determined cones and received the pass back. For the MVIG, the examiner displayed cards with the cone's color for the participant to identify and pass accordingly. (Figure 7)

In the dribbling exercise, the participant had to start by dribbling the cones, then proceed to either the left or right side to dribble the second set of cones using a different technique, and finally shoot to one of the small goals. The MG received complete instructions about the direction, cone color, and target goal beforehand. For the MVEG, the examiner verbally instructed the participants on the color of the cones (red or green) to dribble after the color of the cone in front of the goal

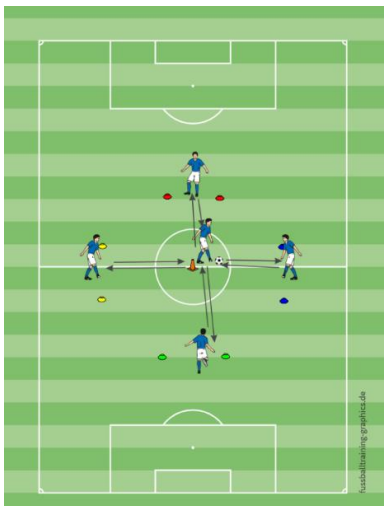
(white or blue) to shoot at. For the MVIG, the examiner showed the participants cards with the color of the cones they needed to dribble and the cone in front of the goal to shoot at. (Figure 8)



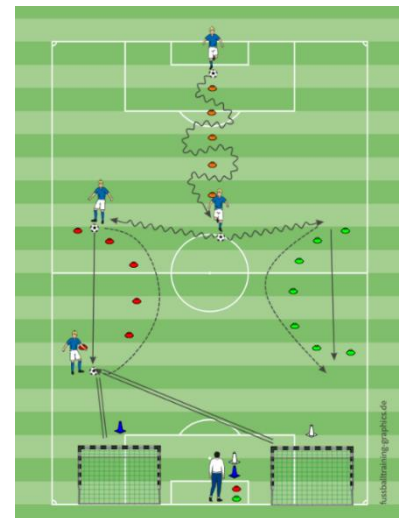
**Figure 5** The Schematic representation of the running exercise.



**Figure 6** The Schematic representation of the shooting exercise.



**Figure 7** The Schematic representation of the passing exercise



**Figure 8** The Schematic representation of the dribbling exercise.

### Statistical Analyses

Group means and standard deviations were computed for all measured and calculated variables. The Shapiro–Wilk tests revealed that all variables were normally distributed, except the anthropometric parameters. In order to detect and measure the differences between groups One-way ANOVA was used.

#### 4. Results

The twenty-four participants were randomly divided into three groups. According to their baseline anthropometric data and training experience, there were no significant differences between them.

**Table 1** Anthropometric data and training experience of the participants (mean  $\pm$  standard deviation).

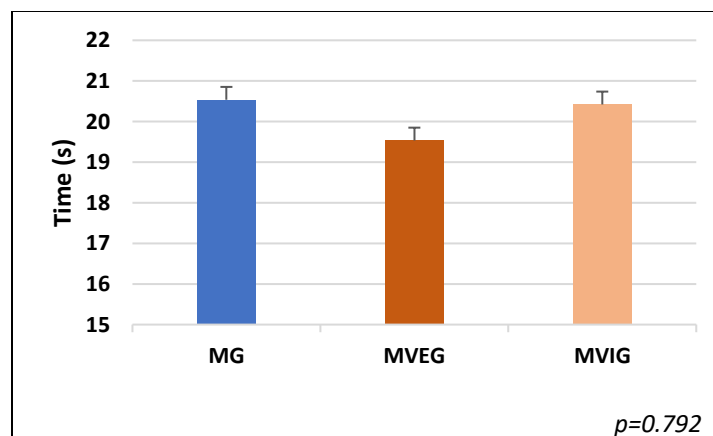
| Variables                  | MVEG              | MVIG              | MG                | P value |
|----------------------------|-------------------|-------------------|-------------------|---------|
| Age (year)                 | 8 $\pm$ 0         | 8 $\pm$ 0         | 8 $\pm$ 0         |         |
| Weight (kg)                | 26.89 $\pm$ 2.56. | 31.09 $\pm$ 6.03  | 32.26 $\pm$ 3.65  | 0.082   |
| Height (cm)                | 131.19 $\pm$ 4.49 | 133.13 $\pm$ 3.56 | 135.00 $\pm$ 5.50 | 0.271   |
| BMI                        | 15.79 $\pm$ 0.88  | 17.32 $\pm$ 2.59  | 17.46 $\pm$ 0.90  | 0.060   |
| Training experience (year) | 2 $\pm$ 0         | 2 $\pm$ 0         | 2 $\pm$ 0         |         |

BMI = body mass index, MVEG = motor-verbal group, MVIG = motor-visual group, MG = motor group,  $p \leq 0,05$ .

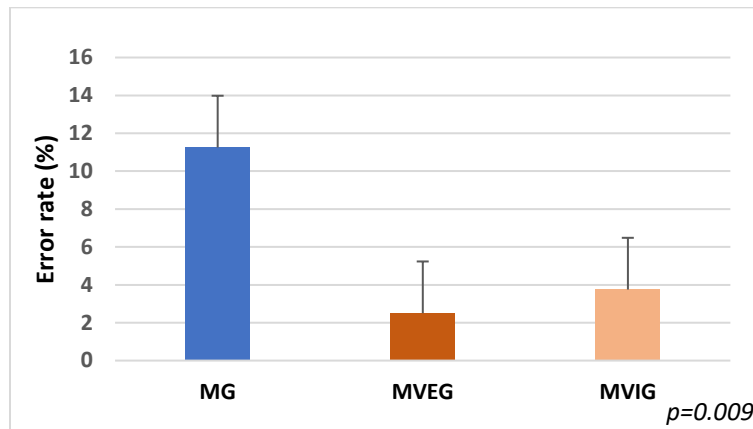
#### Stroop color world test

For the time taken to complete the SCWT, we found no difference between groups ( $p=0,792$ ). (Chart 1) Although the incongruent error rates revealed significant difference between groups ( $p=0,009$ ), where MVEG ( $2.5\pm4.63$ ) and MVIG ( $3.75\pm5.18$ ) both had fewer number of mistakes compare to MG ( $11.25\pm6.41$ ). Amongst the three groups, MVEG reached the lowest error rate. (Chart 2)

**Chart 1** The time taken to complete SCWT.



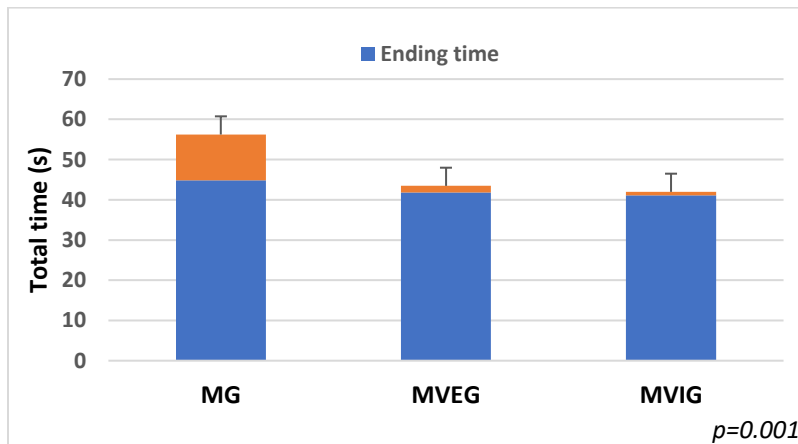
**Chart 2** The sum of the errors in percentage in the Stroop color-world test based on the wrong choices of participants.



### Loughborough soccer passing test

According to the time taken to complete the LSPT test, we registered a significant difference between the three groups ( $p=0.001$ ), where both the MVEG ( $43.45\pm6.04$ ) and MVIG ( $41.97\pm4.21$ ) were able to complete the test in less time compared to the MG ( $56.22\pm8.07$ ). The MVIG group proved to be the fastest with the fewest number of mistakes and added penalty time. (Chart 3)

**Chart 3** Total time of LSPT, including finishing and penalty time.

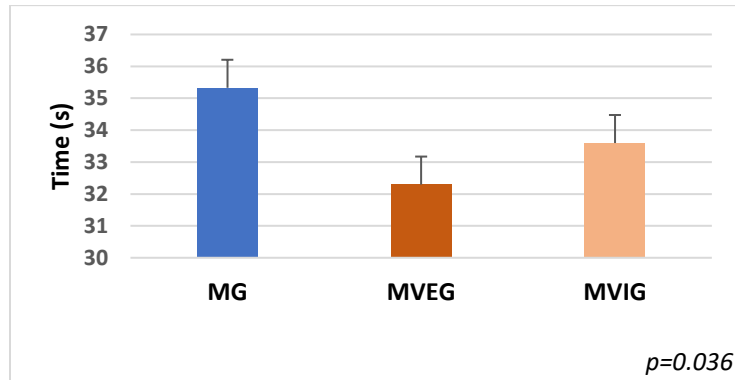


### Illinois ball test

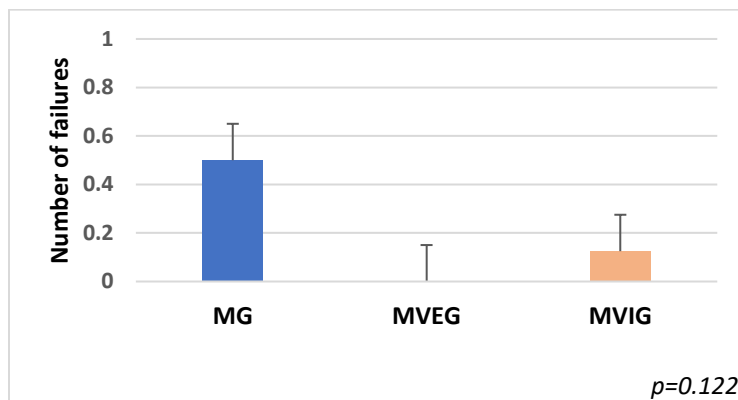
According to the time taken to complete IBT we found significant difference between the groups ( $p=0.036$ ), where both MVEG ( $32.29\pm1.96$ ) and MVIG ( $33.59\pm2.02$ ) finished the test faster compared to MG ( $35.33\pm2.56$ ) and MVEG had better performance compared to MVIG. (Chart 5) In the number of failures, a significant difference between the groups has been registered as well

( $p=0.122$ ). MVEG ( $0\pm0$ ) had the best performance by having no mistakes, followed by MVIG ( $0.13\pm0.35$ ) and MG ( $0.5\pm0.76$ ) had the most amount of fails. (Chart 6)

**Chart 5** The time taken to complete IBT.



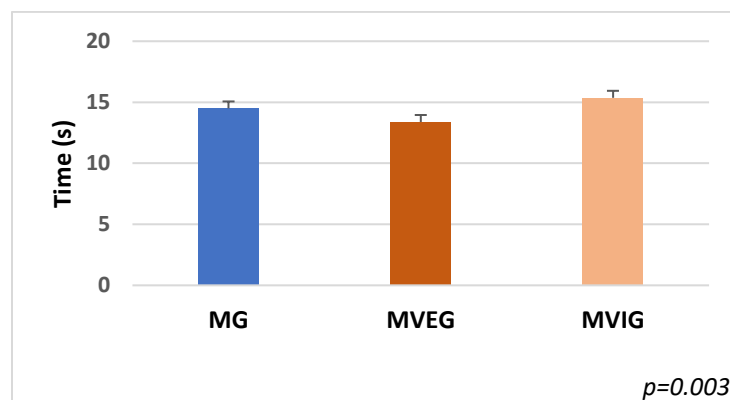
**Chart 6** The number of failures in Illinois ball test.



### T-test

According to the time taken to complete the T-test, we found significant differences between groups ( $p=0.003$ ). MVEG ( $13.38\pm1.02$ ) proved to be the fastest, while MG ( $14.49\pm0.87$ ) was faster compared to MVIG ( $15.36\pm1.08$ ). (Chart 7)

**Chart 7** The time taken to complete the T-test.



## 5. Discussion

The main findings of this study i) there were significant differences between groups in Stroop color-word test error rate, Loughborough soccer passing test time, Illinois ball test time, and T-test time. ii) There was no difference between groups in Stroop color-word test time and Illinois ball test error rate. iii) In Stroop color-word test time and error rate, Illinois ball test time and number of failures and T-test time the MVEG group proved to be the best, whereas the MVIG group also had better performances compared to MG, except T-test, where MG was the second fastest. The MVIG had the fastest time result in the Loughborough soccer passing test followed by MVEG.

**H1:** Regarding our first hypothesis, that the motor-verbal and the motor-visual group will perform at a higher level in the Stroop test, Illinois ball test, and Loughborough soccer passing test compared to the motor group, our data support the hypothesis, except for the Stroop color-word test time. Groups incorporated cognitive tasks into their warm-up protocol demonstrated better performance in inhibition and accuracy. The Stroop test showed that motor-cognitive groups had lower error rates indicating the higher accuracy in choosing the correct option compared to the group that only had motor tasks in their warm-up. Various factors can influence reaction time. The superior performance of the motor-cognitive groups may be attributed to their warm-up protocols, which required enhanced focus to respond to multiple stimuli simultaneously. Consequently, the motor-cognitive warm-up protocol likely improved participants' cognitive abilities to focus on different stimuli simultaneously (Shelton and Kumar, 2010). Illinois ball test demands several cognitive skills such as attention, multi-tasking, and working memory. Where integrated motor-cognitive group performed better than motor group. The motor-cognitive exercises in their warm-up protocol may have enhanced their working memory, allowing them to better remember the order of the test. In contrast, participants in the motor group frequently forgot the test order. This immediate improvement in working memory after motor-cognitive interventions has been supported by other study (Zhang, 2023). Their enhanced attention and multi-tasking abilities may have improved their agility, allowing them to process information more quickly and complete the task faster than the motor group. In addition to football-specific skills like passing and dribbling, the Loughborough soccer passing test requires cognitive abilities such as flexibility, working memory, attention, decision-making, reaction time, and multi-tasking. These skills are necessary for processing the visual and verbal cues from the instructor, selecting the correct target, and

moving to the passing zone to deliver the ball accurately. The superior performance of the motor-verbal and motor-visual groups may be attributed to enhanced working memory, enabling them to remember target locations better than the motor-only group. They also demonstrated better shifting ability, immediately improved after motor-cognitive intervention (Zhang, 2023). Shifting is crucial in this test as participants must switch attention between multiple tasks. We observed no significant differences in the finishing times of the Stroop color-word test between groups. This result is consistent with another study, which found that combined physical and cognitive training did not impact Stroop test performance (Xiang et al., 2023). However, this could be attributed to findings indicating that visual stimuli, as opposed to auditory stimuli, may hinder performance in simple and sequential cognitive tasks (Amon and Bertenthal, 2018). In conclusion, motor-cognitive warm-up protocols that incorporate visual and auditory cues are effective. It is advantageous to include both types of stimuli in the warm-up program. Depending on the training objectives, instructors can adjust the amount of each type of stimulus. For example, if the focus is on dribbling, incorporating auditory-based motor-cognitive warm-ups may be more beneficial, as they improve participants' shifting ability and agility, as shown by the Illinois ball test results.

**H2:** Our second hypothesis proposed that the motor-visual group would outperform the motor and motor-verbal groups in the Stroop color-word test, the Illinois ball test, and the Loughborough soccer passing test. However, our findings do not support this, as the motor-visual group only outperformed the motor-verbal group in the Loughborough soccer passing test. From our perspective, the superior performance of the motor-visual group in this test may be attributed to the visual identification demands of the task. Training with motor-cognitive tasks that included visual cues likely enhanced the players' visual exploration, allowing them to find targets faster. This also improved their working memory, shifting, decision-making, and reaction time, enabling them to remember target locations, switch tasks, and quickly pass the ball with the appropriate power. During their warm-up, participants had to visually explore and recognize the instructor's signs, which may explain their success in the Loughborough soccer passing test. Given that auditory signals reach the brain and are processed faster than visual signals (Ghuntla et al., 2014), it's possible that the quicker response to auditory stimuli influenced the post-training measurements. Research shows that visual and auditory information are processed through different channels requiring distinct mental representations (Amon and Bertenthal, 2018). Factors like fatigue can affect a person's response ability (Pérez-Pacheco et al., 2024). With 83% of

information coming through visual channels and only 11% through auditory channels, visual processing demands more resources than auditory processing (He et al., 2023). Prolonged visual stimulation can lead to neural fatigue (Ioannucci, 2022). Since the motor-visual group's warm-up protocol involved more visual exploration, these findings might explain why the motor-verbal group performed better compared to the motor-visual group. It's important to tailor the type of stimuli in the warm-up protocol to the training objectives. For instance, visual stimuli-based motor-cognitive warm-ups can enhance performance in tasks like passing that require visual exploration and faster reaction time. Therefore, on days when the training focus is on passing and scanning, a visual-based motor-cognitive warm-up might be more beneficial.

**H3:** We initially hypothesized no differences in T-test performance among the groups. Surprisingly, significant differences were observed. The group with integrated auditory stimuli performed the best, completing the test fastest, while the motor group was quicker than the motor-visual group. This suggests that motor-cognitive exercises based on auditory stimuli may be more beneficial for tasks requiring agility. These exercises positively influenced the motor-verbal group's performance in the T-test, which demands high agility. As auditory stimuli-based exercises might be less tiring, the motor-verbal group likely exhibited more coordinated skills than the motor-visual group, leading to better performance. Additionally, motor-cognitive intervention can immediately enhance working memory, enabling participants to change direction faster and remember the test order better than the motor and motor-visual groups. Therefore, incorporating auditory-based motor-cognitive training when the focus is on agility and direction changes can be more beneficial.

This study has several limitations that should be noted. First, we were only able to recruit a small sample size due to the limited availability of players within the same age group and condition. Additionally, since our participants were exclusively male, we couldn't explore gender differences. Future research should examine the short-term effects of auditory and visual-based motor-cognitive warm-up protocols on different age groups and female football players.

## **6. Summary**

To our knowledge, this study is the first to investigate the short-term effects of an integrated motor-cognitive warm-up with visual and verbal stimuli on the football-specific performance of youth male players. It highlights how incorporating visual and auditory stimuli into warm-ups can immediately enhance performance. This method might help players think quicker, react faster and

much more precisely thus performing better on the field. Coaches looking to give their teams an edge should consider adding these kinds of tasks to their routines. While more research is needed, these findings open the door to exciting possibilities for both training and competition.

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