

Cognitive-Motor Dual-Task Ability of Elite Badminton Athletes

Elit Badminton Sporcularının Bilişsel-Motor İkili Görev Yetenekleri

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ABSTRACT

The purpose of this study is to determine the changes in performance duration during motor tasks, which includes the cognitive cues (cue and mixed cue) of elite badminton athletes. The reaction time of 20 Turkish U-19 badminton national team athletes, 10 males ($M_{age}=17.13\pm1.45$) and 10 females ($M_{age}=16.43\pm1.40$) were determined by The FitLight Trainer™. Significant differences were found in favor of cue and mixed cue protocols for male badminton athletes ($p<0.05$). Cue and mixed cue protocols are completed faster than the random protocol for female badminton players ($p<0.05$). This study demonstrates that elite badminton athletes perform postural control adjustments automatically during the motor task. They require minimal less cognitive effort than they need to be minimally considered.

Keywords: Dual-task, Badminton, Elite athletes, Postural control, Cognitive performance

ÖZ

Bu çalışmanın amacı, elit badminton sporcularının bilişsel ipuçlarını içeren motor görevler sırasındaki performans değişikliklerini belirlemektir. 10 erkek ($\bar{x}_{yaş}=17.13\pm1.45$) ve 10 kadın ($\bar{x}_{yaş}=16.43\pm1.40$) olmak üzere 20 Türkiye U-19 badminton milli takım sporcusunun tepki süreleri FitLight Trainer™ ile belirlenmiştir. Erkek badminton sporcularının ipucu ve karışık ipucu test protokollerini, rastgele protokole göre daha hızlı tamamladıkları bulunmuştur ($p<0.05$). Kadın badminton oyuncularının ipucu ve karışık ipucu protokollerinin yer aldığı testleri, rastgele protokole göre daha hızlı tamamladıkları bulunmuştur ($p<0.05$). Bu çalışma, elit badminton sporcularının motor görev sırasında postüral kontrol ayarlamalarını otomatik olarak gerçekleştirdiğini göstermektedir. Bu durum, sporcuların motor görevler sırasında daha az bilişsel çaba sarf etmelerinden kaynaklanabilir.

Anahtar Kelimeler: İkili-görev, Badminton, Elit sporcu, Postüral kontrol, Bilişsel performans

INTRODUCTION

Athletes involved in individual sports need to display effective performance under high levels of cognitive and time pressures. During matches, they often encounter some situations in which they have to maintain their effective performance while fulfilling more than one task such as cognitive and motor tasks (Huang and Mercer, 2001). Dual tasking is a neurophysiological process based on working on both cognitive and motor performance (Mercan, 2016). For instance, in a badminton match, players need to take the correct position to bounce the ball back in time and, at the same time, they need to focus their attention on the body position of their opponent and the orbit of the ball that bounces back. This situation requires certain skills such as attention (Abernethy, 1988; Shiffrin and Schneider, 1977), prediction (Loffing and Canal-Bruland, 2017; Müller and Abernethy, 2012), working memory (Buszard et al., 2017; Furley et al., 2010) and decision making (Baker et al., 2003).

The related studies revealed that expert and experienced players perform better and display more automatic performances when compared to less experienced players (Abernethy, 1988; Beilock et al., 2004; Beilock et al., 2002a; Beilock et al., 2002b; Castiello and Umiltà, 1988; Gabbett et al., 2011; Gabbett and Abernethy, 2013; Schaefer and Scornaienchi, 2020). A high level of automaticity observed in highly talented athletes results in more resistance and successful outcomes in synchronized tasks despite certain levels of decreases in skills under dual-tasking conditions, which leads to more effective multi-tasking performance (Abernethy, 1993).

“Dual-task procedures”, which require individuals to perform two tasks simultaneously, is a common term used to evaluate not only attention demands of predetermined motor skills but also the effects of a secondary task on performance regarding these skills (Huang and Mercer, 2001). However; it is difficult to understand the cognitive mechanism behind this performance when the number of situational stimuli and tasks in dynamic and complex sport environments are considered (Voss et al., 2010). Similarly, attention, which is defined as the allocation of cognitive resources to internal or external stimuli, is a key factor for successful performance (Furley and Wood, 2016). It might be concluded that motor task performance becomes more automatic and requires less attention because of more practice and more experience (Huang and Mercer, 2001; Lam et al., 2009). Raab (2003) examined the effects of low and high task complexity on decision-making in simulated (as a video game) teams and ball games. It has been reported that decisions with low levels of complexity require minimum attention while highly complex decisions cause serious problems both in decisions and motor reactions. Poolton et al. (2006) examined the effects of task complexity on the performances of amateur table tennis players. The possibility of making correct decisions and realization of motor performance is higher for low-complexity cases when compared to highly complex tasks, which implies that increases in task complexity are associated with higher levels of information processing load (Poolton et al., 2006).

Badminton is considered one of the fastest racket sports in the world. Thus, players are expected to be quick in planning and putting their movements into practice, and it requires temporal and spatial accuracy in the racket position to stop the ball with a racket. Also, players need to predict the next movement of their opponents while focusing on their attack and defense actions simultaneously. Better performance in secondary tasks might imply greater attention capacity to be employed while evaluating the opponent's movements. Despite their advantages, dual-tasking performances of elite badminton players have been inadequately studied in the zone. According to the literature review, it is known as the first study in which dual-task analysis was used to determine the reaction times of elite badminton players. This study aims to identify changes in performance times of elite badminton players during motor tasks involving cognitive cues. The study hypothesizes that elite badminton players would complete their tasks without being negatively affected by cognitive additional tasks.

METHOD

Study Design and Group: An experimental design was used as the research design. Participants consist of 10 males ($M_{age}=17.13\pm1.45$) and 10 females ($M_{age}=16.43\pm1.40$) athletes playing in Turkey U-19 national badminton team (Table 1). The criteria for participation in the study were as follows: 1) not having a health problem or injury and 2) participating in the study voluntarily. Informed consent and verbal consent were obtained from all participants before the study. The study received permission from Eskisehir Technical University, Scientific Research and Publication Ethics Committee of Science and Engineering Institute (Protocol No: 87914409).

Table 1

Demographic Information about the Participants

Professional Players	n	Age (Mean±sd)	Height (Mean±sd)	Weight (Mean±sd)	Training Experience (Mean±sd)
Male	10	17.13±1.45 years	177.35±5.13 cm	63.21±6.44 kg	8.57±1.71 years
Female	10	16.43±1.40 years	164.04±5.57 cm	55.03±5.03 kg	7.71±0.95 years

Materials: The data were collected through the Fitlight Trainer™ (FitLight Sports Corp., Kanada) system, which is composed of eight LED lights and used to measure participants' reaction times. The lights might be arranged in different colors and controlled by a tablet computer. Also, the system allows the arrangement of many different protocols as well as which light, when, and how long will be on. Within the scope of the study, the participants were asked to turn off the lights as quickly as possible by touching them with their hands or move their hands over the led lights. A validity and reliability study was conducted for the materials and experimental design (Laessoe et al., 2016).

Data Collection Process: Three different zones (red, blue, and green respectively from left to right) were prepared and a total of 8 lights were used. The zones were placed 1.5 m away from each other, and the red and green zones had two lights each on them while the blue zone had four lights (Figure 1). All the lights were placed according to the height of each participant so that they would be suitable for their hip and shoulder height. All eight lights in the FitLight system were red, blue, and green just like the colors of the zones. Each participant did the test twice and turned off 25 lights in each attempt and the colors of the lights the participants turned off differed in each attempt. Before the actual practice, the participants were asked to turn off the lights in a way different from the protocols to be used so that they could be familiar with the devices and the system. The actual practice started when the participants turned off 5-10 lights (Laessoe et al., 2016; Simsek et al.2021).

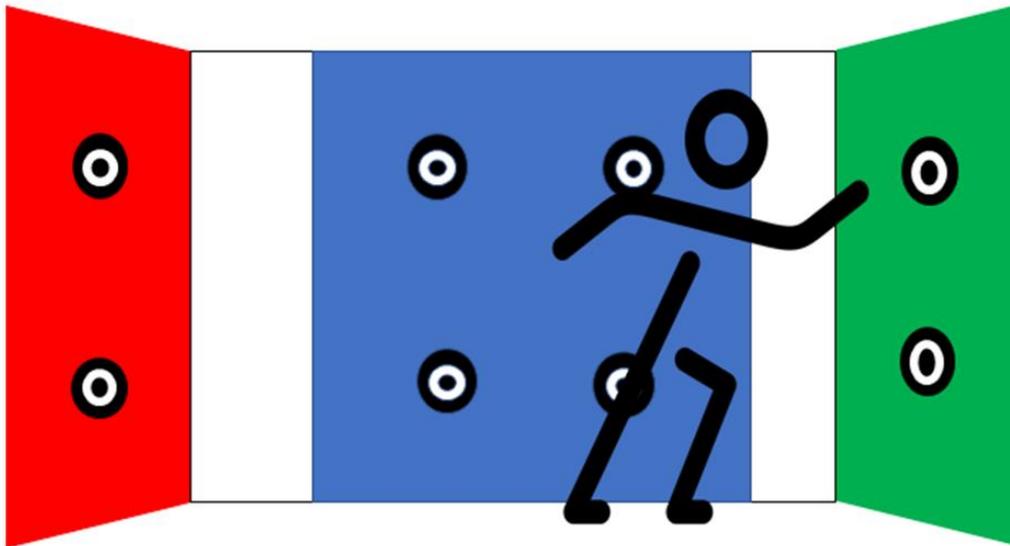
There are three different protocols in the study so that it will be possible to determine the performances of the participants in various methods involving different cognitive contents. To ensure more intensive use of the cognitive process, cues were provided in two protocols. The explanations about the protocols are provided below (Laessoe et al., 2016; Simsek et al., 2021):

1. In the first protocol, the lights were on randomly; i.e without providing any cues for the participants. Thus, this protocol was named the "random" protocol, and the reaction times of the participants were determined according to this protocol.

2. In the second protocol, the color of the light shows the zone on which the next light will be on. Therefore, this protocol is called the "cue" protocol. For instance, if the green light is on, it means the next light will be on in the green zone; if the blue light is on, it means the next light will be on in the blue zone; and if the red light is on, it means the next light will be on in the red zone.
3. The third and last protocol necessitates a more complex cognitive task. Participants' motor control process is expected to differ due to the increase in task complexity; so, this protocol is called the "mixed cue" protocol. The color of the light provides a cue also in this protocol; however, if the green light is on, it means the next light will be on in the red zone; if the red light is on, it means the next light will be on in the green zone; and if blue light is on, it means the next light will be on in the blue zone. For instance, if the light is green and in the blue zone, the next light will be in the red zone. This protocol asks the participants to be involved in more intense cognitive processes and allows them to display their cognitive skills in a dual-tasking strategy. The order of the lights is presented in Figure 1 below.

Figure 1

Test Environment and The Order of Lights: G: Green Zone, B: Blue Zone, R: Red Zone



Mixed Cue

Light Number	8	2	3	4	1	7	2	4	8	7	8	5	2	1	7	3	1	6	4	6	5	7	2	8	1
Color	g	r	g	r	B	b	r	g	g	b	r	B	r	b	g	r	g	b	r	g	r	b	g	r	b

Cue

Light Number	4	1	7	2	3	2	8	5	7	1	4	8	2	6	1	7	3	2	8	4	1	7	5	8	6
Color	r	g	r	b	R	g	b	g	r	b	g	R	b	r	g	b	r	g	b	r	g	b	g	b	b

Random Cue

Light Number	4	1	7	2	3	2	8	5	7	1	4	8	2	6	1	7	3	2	8	4	1	7	5	8	6
Color	g	r	g	b	G	r	b	r	g	b	r	G	b	g	r	b	g	r	b	g	r	b	r	b	b

Before the tests, the participants were informed about the procedures of each protocol. The tests started when necessary permissions were taken from the participants, who were expected to keep their postures and turn off the lights as quickly as possible. There was a 10-minute break before the second attempt. To ensure the validity of the research, the second attempt of each test was used in the analysis. The performance duration of the participants was recorded in seconds (sec) with the fit light system. The system records the times with a precision of two numbers after the decimal point.

Data Analysis: Two chances of attempts were given to the participants and time differences between these protocols for both attempts were analyzed by using SPSS 23.0 (SPSS 23.0, Chicago, IL, USA) software. The Kolmogorov-Smirnov test is used to determine the normal distribution of data. The data were normally distributed. A factorial repeated ANOVA test was used separately for male and female participants to determine performance differences in three different test protocols. Performance improvements for the protocols involving cues were realized according to individual time records. The level of significance was taken as $p < 0.05$ for all the analyses.

RESULTS

Table 2

The Performances of Female and Male Participant Athletes

	Random (Mean±sd)	Cue (Mean±sd)	Mixed Cue (Mean±sd)	PD of Random vs Cue	PD of Random vs Mixed Cue	PD of Cue vs Mixed Cue
Male Athletes						
1st Session	33.30±3.2	25.71±2.7	27.42±2.1	-29.52% *	-21.44% *	6.65% *
2nd Session	31.15±2.6	24.42±1.8	26.12±1.8	-27.55% *	-19.25% *	6.96% *
Female Athletes						
1st Session	35.43±2.4	28.20±2.4	29.59±3.4	-25.63% *	-19.73% *	4.92%
2nd Session	34.34±1.6	26.07±2.3	27.06±2.2	-31.72% *	-26.90% *	3.79%

* $p < 0.05$, scores are given in seconds, **PD**: Percentage of difference.

Table 2 presents the performance durations of male and female badminton players for both sessions according to "random", "cue" and "mixed cue" protocols. According to factorial repeated ANOVA results, a significant difference was found in terms of the protocols of 1st session of male participants ($F_{(2,18)}=99,38$, $p < 0.05$). The results of male badminton players in 1st session for "random vs cue" and "random vs mixed cue" comparisons, there is a significant difference in the advantage of "cue" and "mixed cue" respectively ($p < 0.05$). Also, the "cue" vs "mixed cue" comparisons for male badminton players showed a significant difference in the advantage of the "cue" protocol ($p < 0.05$). In male participants, a significant difference was also found in the analysis results for the protocols of 2nd session ($F_{(2,18)}=61,56$, $p < 0.05$). "Random vs cue", "random vs mixed cue" and "cue vs mixed cue" results of male participants showed significant differences in favor of cue, mixed cue, and cue protocols, respectively ($p < 0.05$).

Results showed that there is a significant difference between protocols of 1st session of female participants ($F_{(2,18)}=91,96$, $p < 0.05$). The results of female badminton players in 1st session for "random vs cue" and "random vs mixed cue" comparisons showed a significant difference suggesting that "cue", and "mixed cue" protocols were completed faster respectively ($p < 0.05$). No significant difference was found for "cue" vs "mixed cue" comparisons in 1st session ($p > 0.05$). In female participants, a significant difference was also found in the analysis results for the protocols of 2nd session ($F_{(2,18)}=224,20$, $p < 0.05$). Similar to the 1st session, a significant difference was found in favor of "cue" and "mixed cue"

in the “random vs cue” and “random vs mixed cue” protocols comparison. No significant difference was found for the “cue” vs “mixed cue” comparison ($p>0.05$).

Additionally, the percentage of differences between protocols for male and female participants are presented in Table 2. Also, when relative developments are concerned, it was found that the participants completed the test more quickly in the “cue” and “mixed cue” protocols than in the “random” protocol. Moreover, the “cue” protocol was completed in a shorter time as shown in the percentage difference than the “mixed cue” protocol.

Figure 2

Performance Durations, Scores are Given in Seconds.

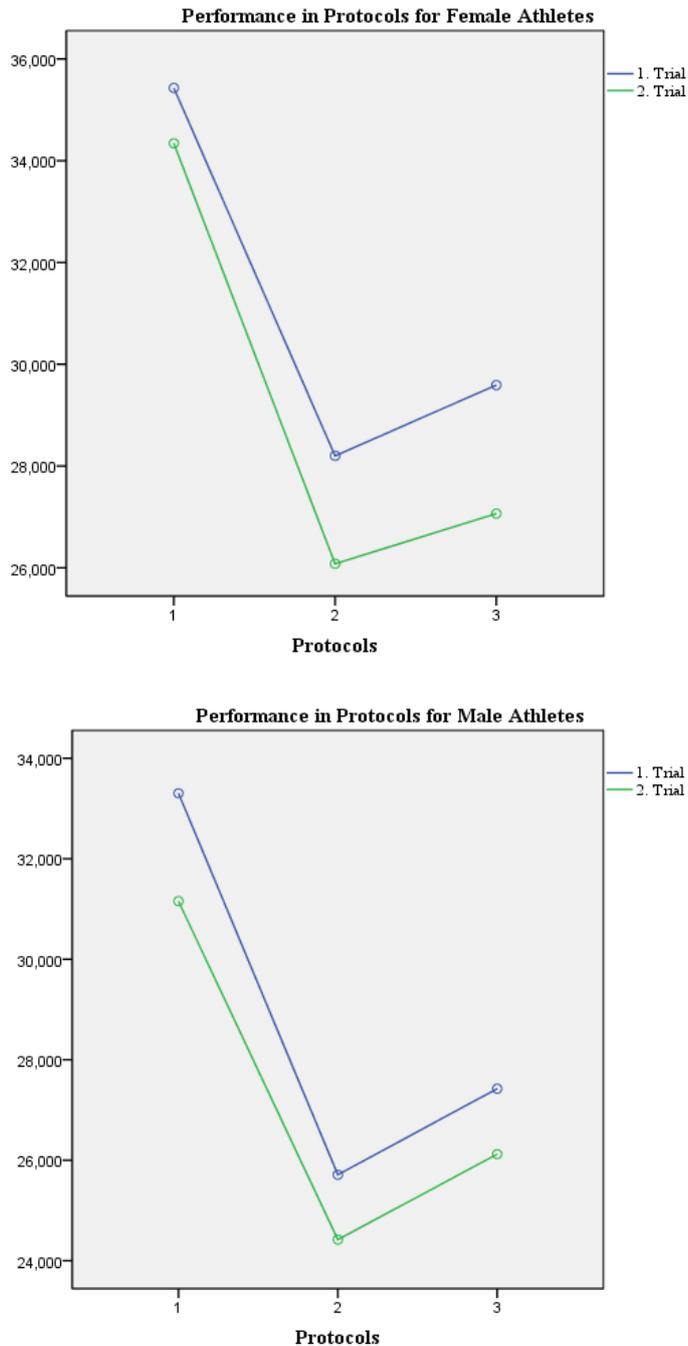


Figure 2 shows that the participants completed the "cue" protocol the fastest in both 1st and 2nd sessions. As for the "mixed cue" protocol, the more complex presentation of cues affected motor performances of the participants, who turned

off the light more slowly than in the "cue" protocol. Both male and female participants completed the "random" protocol the slowest.

DISCUSSION AND CONCLUSION

Athletes involved in team sports often need to display effective performance when they have to fulfill more than one task at the same time during a match. This study aims to determine changes in elite badminton players' performance times during motor tasks involving cognitive cues.

Turning off the lights was taken as the primary task in the current study. Both male and female participants had the lowest times to complete the task in "random" protocol. As for the second protocol, the color of the light shows in which zone the light will be on. In other words, the participants were asked to continue their task performances by using cues. The findings revealed that both males and females had the fastest task completion time in the "cue" protocol in both sessions. When two tasks were completed simultaneously, attention capacity was used effectively among the tasks depending on their difficulty and priority. Also, providing the participants with a cue about where the next light will be on helped them complete the task faster when compared to the "random" protocol.

The 3rd protocol requires a more complex cognitive task. In this "mixed cue" protocol, cues were provided in a more complex way, which affected the motor performances of both male and female badminton players by resulting in slower reaction times to turn off the lights. Our research findings are in parallel with the findings of Abernethy (2001). Performance decreases in 3rd protocol, which includes a secondary cognitive task, may have been caused by the resource demands of the primary task. The more difficult a primary task is, the more attention should be given to the task to maintain an acceptable level of performance (Abernethy, 1988; Schmidt, 1988). In other words, as the difficulty level increases or attention capacity decreases, some problems are likely to occur in one task or both, which implies that dual-task performance necessitates a unity of challenging attention capacities and execution functions (Yogev-Seligmann et al., 2008).

Indeed, the primary task in the third protocol is a complex cue that asks the participant to predict the location of the next light. Thus, it might be concluded that players need more attention and complete the test in a longer time than the second protocol. The results of the current study are consistent with those of the study conducted by Schaefer and Scornaienchi (2020), who examined single and dual-task practices of table tennis players and found a decrease in performance during dual-tasking. A similar study was conducted by Duckworth et al. (2020) who asked 15 individuals to row (full-body and upper-body rowing) and to complete a series of cognitive tasks so that they can display their dual-tasking strategies. The study reported considerable decreases in rowing performance despite the lack of differences in cognitive performance.

The literature review shows that dual-tasking often involves a cognitive task that requires considerable attention and a motor task to be completed together with the cognitive task. The participants display a bad performance during dual-tasking tests when cognitive tasks are added, which is due to low residual capacity (Laessoe et al., 2016; Laessoe et al., 2008). In addition, dual-tasking activities performed by non-athlete individuals were found to result in an acute decrease in both primary and secondary performance; however, the experience might lead to improved performance (Beurskens et al., 2016; Agmon et al., 2015). Similarly, the study conducted by Moreira et al. (2021) concluded that involvement in dual tasks negatively affected performances both in motor and cognitive tasks, and being exposed to dual tasks chronically improved both performances. The current study found that the performances of male badminton players significantly decrease as the number of cognitive tasks increases. On the contrary, no significant difference was found for the

performances of female badminton players although the number of cognitive tasks increased. Similarly, performance decreases were observed for both groups under dual-tasking conditions (Males= 1st Session: 6.65%, 2nd Session: 6.96%; Females 1st Session: 4.92%, 2nd Session: 3.79%). It can be said that the most important factor lying behind the lack of significant difference for females might be their faster adaptation to the test or cognitive tasks.

Cortical executive functions refer to high levels of cognitive processes that use and change information obtained from the cortical sense system (i.e. will power, planning, purposeful action, action monitoring, and cognitive inhibition), which is necessary to generate and modulate actions that are effective in forebrain and hindbrain area and target a purpose as well as to control attention resources (Lezak, 2004). Thus, it might be said that training programs that involve dual-tasking strategies are important in increasing performance in sports. Accordingly, two models were proposed which might account for and support performance changes in dual-tasking. The Task automaticity model is based on automating behaviors through learning the given individual tasks. According to this model, increasing automaticity for a single task is believed to decrease the use of attention resources and increase dual-tasking performance. Repetitions and intense practices might be suggested to increase automaticity. The task integration model deals with working on both tasks simultaneously (Silsupadol et al., 2005; Plummer et al., 2015). According to this model, dual-tasking performance might increase through the integration of tasks. More cognitive and motor resources are necessary for dual-tasking practices since complex tasks activate motor functions and coordination (Silsupadol et al., 2009; Wollesen and Voelcker-Rehage, 2013). The related studies revealed two main strategies. Partial task strategy involves training of each task while whole task strategy is about simultaneous training of both components. The studies report that variable prioritizing techniques (focusing on motor or cognitive tasks) might enhance learning (Yogev-Seligmann et al., 2012). Perumal et al., (2017) in their study focusing on balance, introduced task practices in two different ways - integrated and prioritized- and found that they are effective in walking and balance for all groups. Also, a study conducted with adolescents reported that training programs involving dual-tasking practices have positive effects on balance and cognitive performance. Cognitive load due to secondary tasks improves learning and motor performance (Bustillo-Casero et al., 2020). The research carried out by Lucia et al. (2022) examined the effects of cognitive-motor dual-task training of semi-elite basketball players on sports-specific athletic performance and cognitive functions. The results of the study showed that dual-task training caused a 13% increase in athletes' performances and 25.8% and 5.4% increases in task accuracy and speed respectively when compared to standard training. Moreover, dual-task training improved athletes' attention and brain activities related to decision-making; however, they did not affect effective processing. Therefore, the increase caused by dual-task training both on motor and cognitive performance will positively affect the overall performances of badminton players. Just like in other types of sports, badminton also requires players to complete both motor and cognitive tasks simultaneously. In other words, players need to employ dual-tasking strategies during a match, and dual-tasking practices might positively affect performance. Finally, coaches should introduce dual-tasking training methods as suggested by the research and proposed dual-tasking training methods.

RECOMMENDATIONS

It is acknowledged that elite athletes are believed to be more successful in turning simple and complex skills into automatic performance. High levels of automaticity in highly talented athletes allow them to effectively complete synchronized activities (such as searching for options to make better decisions) and to perform effectively in primary motor tasks. Also, increasing automaticity in primary motor tasks brings an advantage to team sports players by providing a more functional and wider vision. Accordingly, one recommendation for coaches might be to use dual-task practice to

increase the cognitive demands of practice sessions. When we consider the fact that increasing cognitive attempts are associated with more skill learning and retention in motor skill literature, automatized learning might present a useful method to facilitate more learning. Dual-task tests and, perhaps, its practice, seem to provide practical benefits to evaluate and improve at least some team sports skills; however, some scientific evidence is still needed to verify these benefits by conducting further research on the issue. Also, there is a growing need for research focusing on dual-task motor cognitive performance with elite athletes from different types of sports. Finally, it might be suggested that the number of participants might be higher or further studies might be conducted with less experienced athletes.

Authors' Contribution:

- 1. Deniz ŞİMŞEK:** Idea, Data Collection, Data Processing, Writing
- 2. Semra BIDİL:** Literature Review, Data Collection, Data Analyses and Comment, Writing
- 3. Caner ÖZBÖKE:** Idea and Concept, Design, Supervision, Data Analyses and Comment, Writing, Critical Review

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