Examining the time course of attention in a soccer kick using a dual task paradigm

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Abstract:

A dual-task paradigm was implemented using a repeated measures design to determine the time course of attention demands during performance of a soccer penalty kick. Experienced soccer players (N = 15) were asked to perform a 12-yard soccer-style penalty kick. As part of the dual task paradigm, participants were instructed to respond to an audible cue that was administered during one of three probe positions (PP) during the penalty kick. Probe position 1 (PP1) was operationalized as the participant's second to last step (taken with the non-kicking foot), probe position 2 (PP2) was the next to last step (taken with the kicking foot), and probe position 3 (PP3) was the last step (taken with the non-kicking, or "plant foot") just prior to the kicking foot making contact with the ball. Kicks were taken with both the dominant foot (DF) and the non-dominant foot (NDF). It was hypothesized that reaction time to the audible cue (RT) would be slowest at the beginning and end of the performance of the motor skill in both the DF and NDF situations and that RT would be slower when kicking with the NDF, but that the kicking foot would not affect the pattern of attentional demands. Results indicated that RT was slowest at PP1 for both the DF and the NDF and that RT was significantly slower at PP1 for the DF than for the NDF. This suggests that soccer players engage in more complex planning during the preparatory phases when executing a kick with their dominant foot. Future research should be designed to further our understanding of foot dominance with regard to kicking and to explore attentional demands of striking tasks.

Keywords: Attention | Dual-task | Motor processes | Soccer | Bilateral Asymmetry | Foot dominance

Article:

Introduction

Research has been conducted to advance our understanding of the attention demands of particular sport skills. Attention is well defined by William James (1890, pp. 403–404) who stated:

It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which in French is called distraction, and Zerstreutheit in German.

This definition assumes volitional control over when and what we focus our attention on. During sport performance, we are frequently under a barrage of multiple streams of information and must select where to direct our attentional capacities. James' classic definition infers that multi-tasking may require a prioritization of tasks for successful completion of one or both tasks. This definition is consistent with the capacity theory of attention (Kahneman, 1973), which suggests that attention is a limited resource (Singer, Hausenblas, & Janelle, 2001). Based upon this theory, it is expected that the cognitive demands of performing multiple tasks may exceed attentional capacities and performance decrements may appear on one or more tasks.

Given this premise that attention is limited, a dual-task paradigm has been used in research to measure the attentional demands of a specific task (Kahneman, 1973). After providing baseline performance measures, individuals are asked to complete two concurrent tasks while maintaining one of the tasks as their primary task. Their performance on the two tasks performed simultaneously is then compared to their performance on the tasks individually. If performance is maintained on the primary task, but diminishes on the concurrent secondary task (typically a reaction time, RT, task), it is inferred that the primary task required a majority of the individual's cognitive resources and that there were not enough resources remaining to complete the secondary task successfully. If there is little or no decline in the performance of the secondary task, it is implied that the primary task did not require substantial attention and there was sufficient residual processing capacity for both tasks. Thus, the dual-task paradigm can be used to accurately quantify attentional demands during performance of a primary task.

The dual-task paradigm has been used to quantify attention during motor task performance and to make inferences regarding whether or not a person is using implicit or explicit processes in the performance of the task (Lam, Maxwell, & Masters, 2010). Implicit processes are expected to require fewer attentional resources and, hence, to be less vulnerable to interference from other attention-demanding tasks. Explicit processes are expected to require more attentional resources, and this is thought to be reflective of the performer identifying and testing hypotheses related to the achievement of particular outcomes. As a result, explicit processes are expected to be more easily disrupted by performing a secondary task (i.e., the secondary task used in a dual-task paradigm). Of relevance to this study which is focused on understanding patterns of attentional demands during motor task performance is a study testing the time course of attentional demands during a golf putting task performed by novices. Lam et al. (2010) found that when learning the task, performance on the secondary task was worse during the movement preparation phase (prior to the initiation of the backswing) than during execution of the motor task (the forward swing of the putter). Based upon these findings and those of other similar studies (Carson et al., 1999 and Lam et al., 2009), the authors concluded that movement preparation requires greater attentional resources than does movement execution.

Other researchers using dual-task techniques have used more than two probes to further delineate the time course of attention in various motor skills (Castiello and Umilta, 1988, Prezuhy and Etnier, 2001, Price et al., 2009, Rose and Christina, 1990, Sibley and Etnier, 2004 and Singer et al., 2001). In discussing the extant literature, Prezuhy and Etnier (2001) suggested that tasks should be categorized based on their required interactions with external stimuli as this may be the factor driving the pattern of attentional demands. According to Prezuhy and Etnier, gross motor skills such as horseshoe pitching or throwing could be classified as “projection” tasks; receiving a tennis or volleyball serve could be classified as “reception” tasks; kicking a football through the uprights or hitting a golf ball could be considered a “striking” task. Fine motor skills such as pistol shooting could be classified as “aiming” tasks. Prezuhy and Etnier suggest that attentional patterns during the performance of various motor skills may be similar if the required interactions with external stimuli are similar. Hence, it would be expected that the pattern of attentional demands for striking tasks would be similar to those of projection tasks because both require moving an external stimuli towards a target.

The primary purpose of this study was to examine the attentional demands of a soccer penalty kick. The soccer kick falls under the proposed “striking” category of motor skill and will extend our understanding of attentional demands of sport skills by focusing on a striking task that requires the participant to use his/her foot to strike a ball for distance and accuracy. Although striking tasks have not yet been studied using a dual-task paradigm, based upon extant findings with tasks that have been identified as projection tasks, we hypothesize that the attentional demands will be greatest at the start and end of the movement.

A secondary purpose of this study is to examine the influence of dominant/non-dominant foot on the attentional demands of the kicking task. Of further interest in the Lam et al. (2010) study previously described was a finding that after training, attention demands are greater during movement execution for participants who have learned to putt in a manner designed to emphasize implicit learning as compared to those who have learned to perform more explicitly. In this study, experienced soccer players are the participants and hence performance of a penalty kick with the dominant foot (DF) is likely to be an automatized task reliant on implicit processes and less reliant on attentional resources (Beilock, Carr, MacMahon, & Starkes, 2002). However, the use of the non-dominant foot (NDF) is likely to be a much less well-learned motor task and, hence, is likely to result in the commission of more errors during performance. Both of these factors will contribute to performance with the NDF being more reliant on the use of attention to hypothesis test to achieve the desired outcome (Maxwell, Masters, Kerr, & Weedon, 2001). Based upon this rationale, it is expected that attentional demands when taking a penalty kick with the non-dominant foot (NDF) will be greater than with the dominant foot (DF).

Methods

Participants

Participants consisted of fifteen (N = 15) players from local traveling U-16, U-17, U-18, and U-19 soccer teams and university students with previous competitive soccer experience and currently participating in the sport (Table 2). Participant ages ranged from 14-22 (mean age of 17.87 ± 2.39 years). Each participant’s years of soccer playing experience was assessed by self-report. A self-report questionnaire was developed based on the work of Peters (1998) and used to ascertain foot dominance. Only same-side dominant (right-foot and right-hand dominant; left-foot and left-hand dominant) players were invited to participate in this study and all participants were right-hand dominant. Players with previously diagnosed hearing problems were excluded from the study. All procedures were conducted in accordance with the ethical guidelines of the University of North Carolina at Greensboro.

Table 1.

Influence of condition on kick performance and reaction time.

	Kick performance		Reaction time (seconds)	
Condition	Mean	SD	Mean	SD
NDF Baseline	1.26	0.29	–	–
NDF PP1	1.47	0.34	0.35678	0.10247
NDF PP2	1.35	0.76	0.33546	0.09460
NDF PP3	1.26	0.75	0.36725	0.12313
NDF Catch	1.37	0.73	–	–
DF Baseline	1.49	0.35	–	–
DF PP1	1.45	0.74	0.38864	0.13052
DF PP2	1.39	0.72	0.33140	0.10767
DF PP3	1.40	0.76	0.34719	0.11819
DF Catch	1.37	0.76	–	–
RT Baseline	–	–	0.31135	0.0859

Note: Possible performance scores = (0–2). Probe position 1 (PP1) was operationalized as the participant's second to last step (taken with the non-kicking foot), probe position 2 (PP2) was the next to last step (taken with the kicking foot), and probe position 3 (PP3) was the last step (taken with the non-kicking, or "plant foot") just prior to the kicking foot making contact with the ball. Tests were performed with both the dominant foot (DF) for kicking and the non-dominant foot (NDF) for kicking. A catch trial is when the participant is instructed to perform the primary task and is prepared to response to the auditory stimulus, but the stimulus is not presented. Baseline measures were collected for performance on each task separately. DF = dominant foot; NDF = non-dominant foot.

Table 2.

Participant demographics.

Subject	Age (years)	Gender	School affiliation	School experience (years)	Club experience (years)	Additional experience (years)	Position
001	19	Female	College	8	2	0	D, M
002	19	Female	College	6	8	0	F, M
003	19	Female	College	7	2	0	D, M
004	18	Female	High School	10	7	4	D, M
005	15	Female	High School	3	7	0	M, F
006	15	Female	High School	1	6	0	M
007	18	Male	High School	4	6	3	D
008	21	Male	College	4	3	0	D
009	19	Female	College	3	0	0	F
010	15	Male	High School	4	6	0	M, F
011	22	Male	College	6	2	0	M
012	20	Male	College	2	0	0	M
013	14	Male	High School	4	4	2	M, F
014	16	Female	High School	3	12	3	M, F
015	18	Male	High School	4	6	3	F, M

Measures

Testing was conducted based on the regulations of the Federation Internationale de Football Association (FIFA). Testing occurred on a natural-grass soccer field. A FIFA-regulation soccer goal was placed twelve yards away from the testing station. To maintain consistency while simulating the difficulty in shot placement required during a penalty kick, the goalkeeper was replaced with three scoring zones. The goal was reduced to smaller “scoring zones” for scoring purposes. The primary target was the two outer zones measuring inward two-yards from the goal posts. A secondary target goal was the remaining four-yards located between the outer scoring zones (see Fig. 1). Target zones were distinguished by 1-inch PVC tubes spanning the full height of the goal. The participant placed the ball at the penalty spot before each trial. Scoring was based on successful execution of the task with the ball passing through the scoring zone. If the ball passed through either of the primary targets, the participant was awarded two points. If the ball entered through the secondary target (the center of the goal), the participant received one point. If the ball failed to cross the goal line, the participant received zero points for that trial. Participants were instructed to perform the kick as if they were doing so in a game situation and, hence, were free to shoot into any scoring zone on each kick.

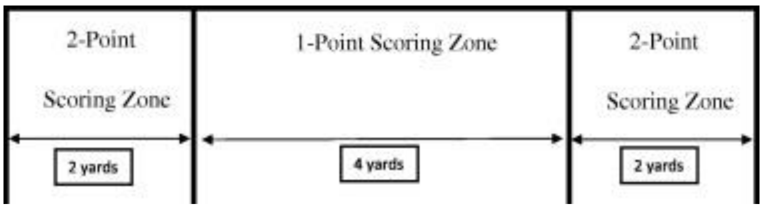

Fig. 1.

Soccer kick task design.

The secondary task used in this study was a verbal response task that provided a measure of RT. A laptop equipped with external speakers was used to deliver the auditory stimuli and a digital voice recorder was used to record the participant's response. The Olympus WS-400S digital voice recorder and ME-52W noise-cancelling microphone were selected due to their lightweight and portable design. The WS-400S digital voice recorder is 3.70 by 1.50 by 0.40 inches and weighs 1.60 ounces. The ME-52W microphone is 4.40 by 2.00 by 0.80 inches and weighs 0.50 ounces. The ME-52W was selected to ensure optimal uni-directional recording in an outdoor setting. The ME-52W optional tie-clip was also used to ensure that the microphone would stay in place while the participant was in motion. The wireless recording devices that were used allowed the participants' unrestricted movement compared to a traditional wired headset/microphone.

Audacity 1.3.7 (Mazzoni, 1989, Boston, MA) is an open source audio editor and recorder. This software was used to record the auditory stimuli as well as the participant's verbal response. The software includes a spectrogram and "plot spectrum" analyzer for detailed frequency analysis. Following procedures defined by Price et al. (2009), RT was defined as the time from the beginning of the computer-generated tone to when the verbal response reached a waveform amplitude of 0.1 dB. Recordings were enlarged and slowed to 20% of the original speed to provide accurate analysis. The beginning of the auditory tone was determined as the initial burst in waveform activity. The envelope editing tool, native to Audacity software, was used to determine the 0.1 dB threshold for verbal response. The point at which the verbal response waveform first reached the defined threshold was determined to be the conclusion of RT. Aural and visual identification was used to determine the start and stop of each RT measurement. RT was measured with a resolution of 0.0001 seconds. To ensure experimenter accuracy in providing the auditory stimulus at the intended probe point, digital videotaping was also conducted during the pilot testing sessions. Video files were analyzed by an external collaborator.

The tone was administered manually by the experimenter through the Audacity 1.3.7 software. The tone was a computer-generated, 2000 Hz tone that lasted 0.350 s. The participant was instructed to respond to the tone as quickly as possible with a predetermined verbal cue. "BALL" was used as the verbal cue for the dual-task model of this experiment. According to previous research (Beilock et al., 2002 and Ford et al., 2005), attending to component processes during the execution of a proceduralized task can negatively impact performance. However, external task-irrelevant cues have been shown not to interfere with performance of well-learned tasks in experienced athletes (Ford et al., 2005).

Procedures

Participants provided their consent to participate on a form approved by the University's Institutional Review Board. Parental consent and participant assent forms were used for participants under 18 years of age. Participants then completed a demographic questionnaire detailing age, previous soccer experience, position most frequently played, current medications, current level of fatigue, acute/chronic injuries, and dominant hand/foot.

Baseline performance measures for both tasks were established prior to testing. Participants were asked to complete a standardized dynamic warm-up protocol to minimize the risk of musculoskeletal injury during testing. Participants then performed ten kicks with their DF and ten kicks with their NDF that were scored for performance comparison purposes. Then, without kicking the ball, the participant stood behind the ball as if he/she were going to perform the kick. After the participant was given the "ready" signal, he/she was asked to respond to the auditory tone as quickly as possible with the verbal cue, "BALL". The presentation of the auditory tone was presented at random within two seconds after the ready signal was given. Ten RT trials were averaged and then used as the baseline for secondary task performance comparisons.

Three probe positions (PP) were used during performance of the soccer penalty kick. Probe position 1 (PP1) was operationalized as the participant's second to last step (taken with the non-kicking foot), probe position 2 (PP2) was the next to last step (taken with the kicking foot), and probe position 3 (PP3) was the last step (taken with the non-kicking, or "plant foot") just prior to the kicking foot making contact with the ball. The participants were instructed that the primary task was to accumulate the highest score possible by kicking the ball through the designated scoring zones. A second observer examined each trial for a randomly selected participant during pilot testing to ensure that distinct probe positions were easily identifiable and that the tone was accurately administered according to the operational definitions.

Participants were informed that the experimenter would select which foot (DF or NDF) they were to kick the ball with prior to each trial. Catch trials were included to minimize the participant's ability to anticipate the presentation of an audible tone. A catch trial is when the participant is instructed to perform the primary task and no dual-task stimulus is presented. This reduces participant anticipation effects and maintains focus on the primary task performance, thus ensuring more accurate RT during trials with probe positions. In total, participants completed ten trials at each probe position as well as ten "catch" trials for a total of forty trials with each kicking foot. These trials were presented in a random order with respect to probe administration (PP1, PP2, PP3, or catch) and foot (DF, NDF). Presenting the probe points in random order as well as the inclusion of catch probes minimizes methodological concerns (Abernethy, Summers, & Ford, 1998).

Data analysis

RT from the ten trials at each probe position were averaged and used as the dependant measure. The two independent variables were probe position (PP1, PP2, PP3) and kicking foot (DF, NDF).

With the dual-task technique, it is important that the primary task be given attentional priority. To ensure that the primary task remained the priority, a two-way repeated measures analysis of variance (RM ANOVA) was used to compare kick performance across conditions (the three probe positions, catch trials, and baseline) and as a function of the kicking foot (NDF, DF). To examine the time course of attentional demands and test the hypotheses of the study, RT was examined using a two-way RM ANOVA with kicking foot (DF, NDF) and probe position (PP1, PP2, PP3) as the within-subjects independent variables.

Results

Means and standard deviations for kicking performance and RT are presented in Table 1

The results from the 2-way RM ANOVA for performance on the primary task showed that there was no significant difference as a function of kicking foot, $F(1, 56) = 1.59$, $p > .05$, partial $\eta 2 = 0.10$, condition, $F(4, 56) = 0.86$, $p > .05$, partial $\eta 2 = 0.06$, or the interaction of kicking foot by condition, $F(4, 56) = 2.28$, $p > .05$, partial $\eta 2 = 0.14$.

The results of the 2-way RM ANOVA for RT indicated that the main effect for probe position was not significant, $F(2, 28) = 3.28$, $p = .053$, partial $\eta 2 = 0.19$. The main effect for foot was also not significant, $F(1, 14) = 0.17$, $p = .69$, partial $\eta 2 = 0.01$. However, there was a significant interaction of probe Position × Foot, $F(2, 28) = 6.09$, $p = .006$, partial $\eta 2 = 0.30$, see Fig. 2. For the NDF, follow-up tests indicated that PP1 was significantly different from PP2, $t(14) = 2.30$, $p < .05$, but that neither PP1 nor PP2 were significantly different from PP3, $p > .05$. In the DF, follow-up tests indicated that PP1 was significantly different from PP2, $t(14) = 3.42$, $p < .05$, but neither PP1 nor PP2 were significantly different from PP3, $p > .05$. Follow-up tests for comparisons between PP as a function of foot indicated that only PP1 was significantly different between kicking foot, $t(14) = -3.98$, $p < .05$. Neither PP2 nor PP3 were significantly different as a function of kicking foot, $p > .05$.

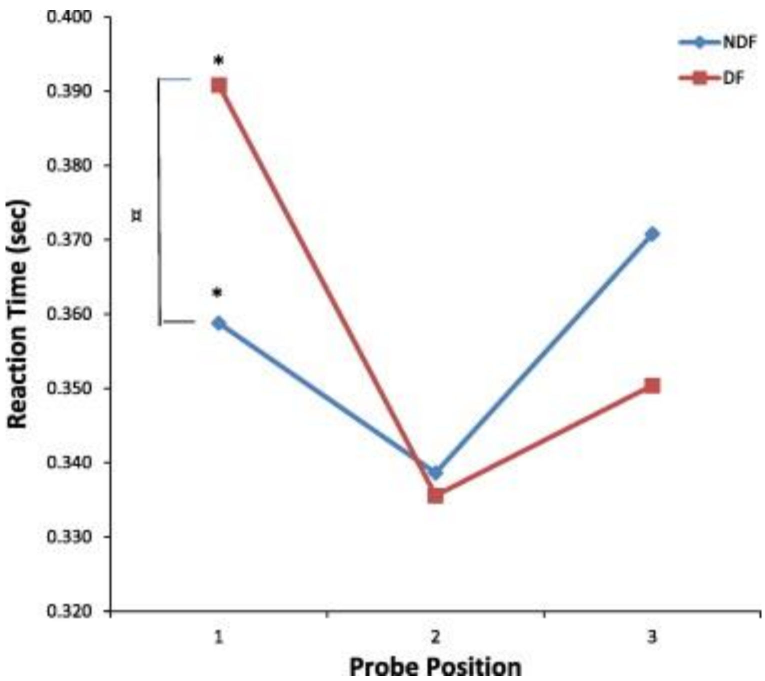

Fig. 2.

Influence of Condition × Probe Position on reaction time. *Note:* NDF = non-dominant foot; DF = dominant foot; PP = probe position. * = means are significantly different from PP2; ¤ = means are significantly different from one another. Probe position 1 (PP1): the participant's second to last step (taken with the non-kicking foot), probe position 2 (PP2): next to last step (taken with the kicking foot), and probe position 3 (PP3): last step (taken with the non-kicking, or "plant foot") just prior to the kicking foot making contact with the ball.

Discussion

The purpose of this study was to examine the time course of attention during a soccer penalty kick and to determine the impact of the use of the DF and the NDF as the kicking foot. Because kick performance did not differ across probe positions as compared to baseline performance measures and catch trials, it can be assumed that primary task focus was maintained (Prezuhy & Etnier, 2001); thus changes in RT can be attributed to varying degrees of attentional demand inherent in the primary task. The first hypothesis of this study stated that the pattern of attentional demand of this striking task would be similar to that of previous research featuring projection tasks: specifically, it was expected that attentional demand would be greatest at the start and end of the movement. This hypothesis was partially supported. Regardless of which foot was used as the kicking foot, attentional demand was high at the start of the movement (as judged from RT being the slowest at PP1). However, attentional demand was not significantly different between the middle phase of the movement and the end of the movement. The significant differences in RT between PP1 and other probe positions suggest that the initial phase of the movement is the most attention demanding and subsequently vulnerable to distraction. This finding is in line with previous research using projection tasks (Prezuhy and Etnier, 2001, Price et al., 2009 and Sibley and Etnier, 2004) and using a striking task (Lam et al., 2010). However, there were no significant differences found between PP3 and other probe positions. The fact that attentional demands in this striking task were not high at the end of the movement may lend support to previous research suggesting that striking tasks are not, in fact, similar to projection tasks with regards to the attentional demands (Sibley & Etnier, 2004). However, it is also possible that the third probe position did not come near enough to the end of the execution of the skill to capture heightened attentional demands in the performance of this sport skill.

The second hypothesis of this study stated that attentional demands when taking a penalty kick with the non-dominant foot (NDF) would be greater than with the dominant foot (DF). This hypothesis was not supported; there were no significant differences in RT at PP2 or PP3 when comparing the NDF and DF. However, there were differences in RT as a function of kicking foot such that RT was slower at PP1 in the DF condition than the NDF condition. The higher attentional demands observed at PP1 for the DF may reflect that the athlete has greater confidence in kicking with this foot and, therefore, pre-plans some aspects of his/her performance (which might require more attention). Players may determine the location of their shot, the force required for the shot, and the bend of the ball's trajectory. These "higher order" considerations at the initiation of the kick are highly elastic aspects of the kick and are subject to change from one kick to the next. Therefore, the planning of these aspects of a kick with the DF are likely to be governed by explicit processes as an increased number of hypotheses related to achievement outcomes are being tested by the movement. If players have concerns about their ability to strike the ball as might be the case when taking a penalty kick with their NDF, they may allocate their resources on more fundamental aspects of the motor skill and limit thoughts about more challenging components of the kick. Thus, at the initiation of the movement with the NDF, experienced players may be more likely to focus on more basic, implicit processes such as taking the correct number of steps and solidly striking the ball. These aspects of the kick, which have become highly proceduralized over time likely require less attentional resources and may help explain differences in RT at PP1 in the current study. If players are comfortable with their ability, they may tap into available resources to execute those higher order tasks and this may be reflected by higher attentional demands earlier in the approach when kicking with their DF.

Before discussing directions for future research, it is important to note the limitations of the study. One limitation of the study was the lack of performance measurement sensitivity that resulted from the use of three scoring zones within a standard soccer goal. While attempts were made to maintain high ecological validity, these results may not generalize to real-world performance. Although the scoring zones were meant to mimic the demands of a real penalty kick by providing greater reward for kicking the ball into the outer edges of the goal, this is clearly not the same as taking a shot to avoid a goal keeper attempting to block the shot. Future study would benefit from a more precise method of scoring and external generalizability would be enhanced by incorporating a goal keeper. Additionally, the use of only three probe positions means that the time course of attention across the entire performance was not examined. Future research that allows for RT to be assessed at more points during the execution of the penalty kick will allow for a more comprehensive understanding of the attentional demands of the task. In particular, given the importance of ball contact to the execution of the kick, our understanding of the attentional demands of the penalty kick would be informed by the inclusion of a probe position at ball contact. Lastly, the participants were presumed to be skilled at taking penalty shots with their DF because they were all members of travelling soccer teams (which are the most competitive youth club teams) or because they played collegiate soccer (Table 2). However, we were not able to assess soccer skill or skill at taking penalty shots directly and, hence, future study will be necessary to explore potential differences in attentional patterns as a function of skill level. Future research should also be directed at other skills that would fall under the classification of “striking” tasks. Sport skills such as, soccer passing, soccer and football punting, football place kicking, are just a few examples of such tasks with similar requirements.

In summary, the findings of this study generally suggest that the attentional demands at the initiation of a soccer penalty kick vary based on unique factors associated with implicit or explicit processing. Specifically, players are allocating the largest portion of their attentional resources at the initiation of the kick, especially when kicking with the dominant foot. It is recommended that players and coaches establish a routine and emphasize sound technique during the preparation phase of a penalty kick that will help isolate them from distraction during this critical period in which attentional resources are in high demand. Research analyzing the efficacy of dual-task methodology for skill development in sport is limited. However, Gabbett, Wake, and Abernethy (2010) found that an 8-week dual-task training program afforded some benefits to highly skilled rugby players in dual-task draw and pass proficiency tests. Further studies are required to assess the effectiveness of utilizing dual-task training on skill acquisition and skill performance in sport.

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