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Research article

Investigating the Contextual Interference Effect Using Combination Sports Skills in Open and Closed Skill Environments

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Abstract
This study attempted to present conditions that were closer to the real-world setting of team sports. The primary purpose was to examine the effects of blocked, random and game-based training practice schedules on the learning of the field hockey trap, close dribble and push pass that were practiced in combination. The secondary purpose was to investigate the effects of predictability of the environment on the learning of field hockey sport skills according to different practice schedules. A game-based training protocol represented a form of random practice in an unstable environment and was compared against a blocked and a traditional random practice schedule. In general, all groups improved dribble and push accuracy performance during the acquisition phase when assessed in a closed environment. In the retention phase, there were no differences between the three groups. When assessed in an open skills environment, all groups improved their percentage of successful executions for trapping and passing execution, and improved total number of attempts and total number of successful executions for both dribbling and shooting execution. Between-group differences were detected for dribbling execution with the game-based group scoring a higher number of dribbling successes. The CI effect did not emerge when practicing and assessing multiple sport skills in a closed skill environment, even when the skills were practiced in combination. However, when skill assessment was conducted in a real-world situation, there appeared to be some support for the CI effect.

Key words: Blocked practice, random practice, practice schedules.

Introduction

From a coaching perspective, it is important that a practice session is organised in a way that will benefit learning and keep athletes motivated to attend practice. From a motor learning perspective, variable practice (practicing multiple skills in a practice session) provides for variety to keep athletes motivated, while the knowledge from the contextual interference (CI) effect phenomenon ensures that learning has taken place. This CI effect is created when motor skills are practiced following a random order whereby performance following practice is decreased but substantial learning has taken place. An opposite effect is derived from practicing skills in a repetitive or blocked order, whereby performance is enhanced following practice, but with little or no learning benefits.

The explanation for the CI effect has been largely postulated by Lee and Magill's (1985) action-plan reconstruction hypothesis and Shea and Zimny's (1983) elaboration hypothesis. Lee and Magill (1985) proposed that the degraded performance in random practice was due to a task being forgotten and learning was enhanced because a new and different preparation for action was reconstructed each time a task was executed. As for the elaboration hypothesis, the inter task processing in random practice allows the learner to compare and contrast his actions making them more distinct and meaningful to the learner. More recently, Lin et al. (2008) used transcranial magnetic stimulation (TMS) pulses to investigate whether the action-plan reconstruction hypothesis or the elaboration hypothesis was a better explanation for the CI effect. The authors found stronger support for the elaboration hypothesis.

Regardless of which hypothesis was used to explain the CI effect, there appeared to be significant evidence that the CI effect was present in studies involving laboratory motor tasks. However, when the CI effect was studied using applied sport skills, the results have been mixed. In the case where a positive effect from the high interference practice schedules were not found, it has been suggested that the mitigating factor could be the complexity of the sports skills practiced (e.g., Jones and French, 2007; Landin et al., 2003; Zetou et al., 2007). A moderate practice schedule was proposed as a solution to the problem but attempts at manipulating the amount of interference of practice schedules still failed to provide a clear trend pertaining to the CI effect.

As such, is it possible that there is another way to reduce the difficulty of the sports skills being practiced? Most previous research addressing the contextual interference (CI) effect in applied sport settings have focused on multiple skills practiced independent of one another (e.g., Farrow and Maschette, 1997; Fialho et al., 2006; Granda Vera et al., 2008; Jones and French, 2007; Zetou et al., 2007) and in a closed skill manner (e.g., Brady, 1997; Landin et al., 2003; Meira and Tani, 2003; Porter and Magill, 2010; Wrisberg and Liu, 1991). In the majority of team environments, practicing a skill in isolation or independently in a closed skill environment does not represent the real-world setting of team sports. In a typical game setting, several skills (both discrete and continuous) often need to be executed one after another, and a combination skill is performed in order to achieve a particular outcome. In addition, an important aspect of a typical game is that it occurs in an unpredictable environment, whereby the type of skill a player executes is dependent upon the regulatory features (in particular: teammate and opponent movements) of the environment. While a number of stud-

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ies that have attempted to bring CI research out of the laboratory by investigating applied sport skills and activities of daily living, there remains no pertinent literature examining combination skills. Furthermore, it appeared that only one study has investigated the CI effect with open sports skills. In that study, Granda Vera and colleagues (2008) compared three groups (blocked, alternating and combined) of children that practiced two soccer skills, kicking and dribbling.

Therefore, the purpose of this study was twofold. The first aim was to investigate the effects of three practice schedules located on the contextual interference continuum on the learning of combination skills. Practicing a set of skills in combination creates a functional skill that mirrors the way skills are executed in game play. A second purpose of this study was to investigate whether practicing skills randomly in an open skills environment could elicit the CI effect. A game-based training protocol was chosen to represent a random schedule with an unpredictable environment. As such, a more specific aim of this second purpose was to examine if a game-based training protocol is an effective form of high interference practice for skill learning. A review by Gabbett et al., (2009) found that while game-based training appeared to be a valuable tool for improving skill execution in team sports, the number of studies investigating its effectiveness was quite small and only focused on immediate skill execution but not retention performance. There have been no studies that had investigated the use of real-world game-based training (without conditioning or other activities) to assess acquisition and learning of sports skills in relation to the CI effect.

It was expected that the CI effect would be present when several sports skills were practiced in combination. Furthermore, practicing sports skills according to the game-based training protocol representing a random practice schedule in an unpredictable environment would be superior to the blocked and random group because of their exposure to the demands of a game and practicing in a similar environment. At the very least, the game-based schedule should be no worse than the random practice schedule characterised by a stable environment.

Methods

Participants

A total of 48 male and 22 female undergraduate students with a mean age of 21.56 and standard deviation of 1.23 (range between 19.17 to 26.67 years) volunteered to participate. The participants were first screened to determine that they had no prior experience in field hockey, had never received field hockey skills coaching and never played a competitive hockey match. All participants were given a copy of the information sheet and returned the signed informed consent form in accordance with the ethical guidelines of the Human Ethics Committee.

Tasks

Two combinations of basic field hockey skills were practiced. In combination 1, participants were required to (1) stop the ball that was heading in their direction, then (2) close dribble and move with the ball in a straight line with the ball positioned next to the hockey stick at all times and then (3) push the ball as fast and as accurately as possible toward another participant. For combination 2, participants were required to simply stop the ball that was heading in their direction before pushing the ball as fast and as accurately as possible toward another participant.

Measures and test instruments

Skill performance test

The skill performance test was used for the pre-test, acquisition and retention tests, whereby the close dribble and the push pass were assessed. For the close dribble, the speed of the participant dribbling with the ball over a distance of 10 m was captured while for the push pass, the speed and accuracy of the ball toward a target was recorded.

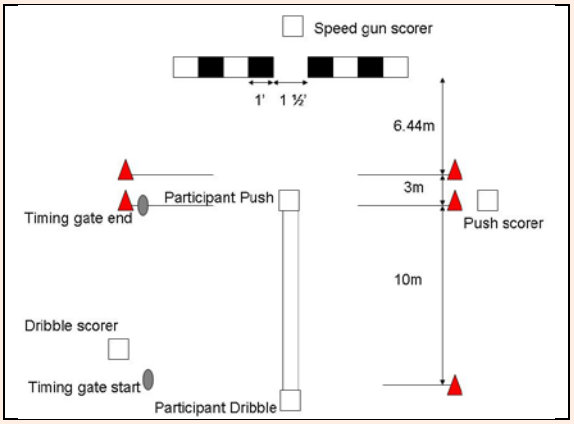

Figure 1. Layout for the skill performance outcome test used in the pre-test, acquisition and retention tests.

Figure 1 illustrates the layout for the skill performance test that was used in the pre-test, acquisition test and both retention tests. A speed gun (Bushnell Speedster II) quantified ball speed in km/h for the push pass. In addition, two four-foot long, two by three inch thick blocks of wood was used as the target. Scoring ranged from one to five points.

Game performance test

The game performance test was used as a transfer test whereby a pre and posttest was carried out. A four versus four game was played for seven minutes with specific rules introduced for the game. All participants played against four of five state-level field hockey players. The game play observational instrument designed by Turner and Martinek (1999) was adapted to assess motor execution. Two categories of behaviour was coded, one for control and the other execution (see Table 1).

The game performance test was coded according to the recommendations by Turner and Martinek (1992) which included observing one player at a time and repeating the same procedure for different players on the team. The investigator and two independent coders viewed and coded all video recordings. The median score was used and the inter-tester reliability was calculated using intra-

Table 1. Game performance coding protocol for control and execution.

Control	Coded as 0	Coded as 1
a) Trapping	1. Unsuccessful control. 2. Using back of stick. 3. Ball contacting feet.	1. Successful control.
Execution		
a) Passing	1. Pass too hard. 2. Pass out of bounds. 3. Too far behind or in front of team mate. 4. Intercepted pass.	1. Successful pass to team mate.
b)Shooting	1. Shot off target. 2. Intercepted or blocked shot.	1. Shot on target. 2. Goal scored
c) Dribbling	1. Loss of control.	1. Successfully advancing the ball.

class correlation (ICC). The ICC for all coded behaviours was above 0.70. By convention, values above 0.70 are considered as substantial and acceptable inter-rater reliability (Garson, 2013).

Experimental practice groups

The three experimental practice groups chosen for this study were categorised according to their location along the contextual interference continuum. The blocked (n = 24) protocol represented low interference conditions, while random (n = 20) and game-based (n = 24) protocols represented high interference conditions. Besides the location on the contextual interference continuum, another important distinction between the groups was the stability of environmental context. Participants in the blocked and random groups were in a self-paced, stable environment whereas participants in the game-based group were in an externally-paced, unstable environment. Locations of these three experimental groups along the CI and stability continua are graphically displayed in Figure 2.

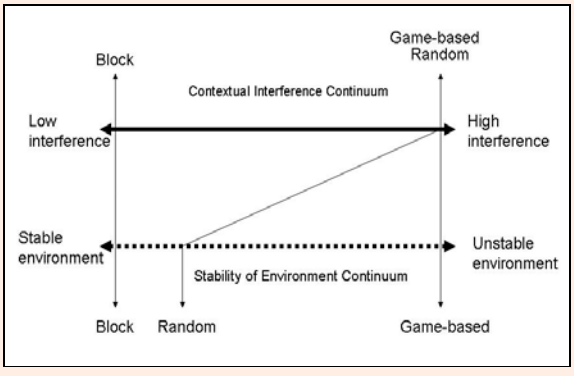

Figure 2. Locations of the three experimental groups on the contextual interference continuum and stability of environment continuum.

Procedure

The duration of the study was six weeks, and participants were required to attend a total of ten sessions. In the first introductory session, the procedures were outlined and background information and consent sheets were distributed. In the second session, a skill demonstration session and the pre-test took place. Participants were subjected to the skill performance pre-test which consisted of five trials of the close dribble and push pass. Subsequently, the game performance pre-test was also administered where a state hockey player refereed a seven-minute four-versus-four game that was videotaped and subsequently coded. Next, participants attended six acquisition sessions which comprised of the acquisition practice and acquisition test. For the practice, participants attended two sessions each week for three weeks according to a pre-determined timetable.

During acquisition practice, participants were divided into groups of four. Participants in the blocked group had two different practice stations, blocked station A and blocked station B. At station A, participants practiced only one combination which was the trap, close dribble and push pass around the equilateral triangle (10 m lengths) as depicted in Figure 3(a). For example, a participant would dribble the ball for approximately five metres before pushing the ball to the next participant, then jog to the next cone. The participant to whom the ball was pushed would repeat the trap, dribble and push to the next cone/participant. At station B, participants practiced the other combination of the trap and push pass within a square whereby a participant could push the ball to any other participant in the group (see Figure 3(b)).

As depicted in Figure 3(c), participants in the random group practiced both combinations in a layout similar to blocked station B but different coloured cones were used. Figure 3(d) is an illustration of the practice area for participants in the game-based training group. Participants in this group formed a team of four players practicing against three opponents that did not tackle but could intercept the ball. Only one combination was practiced in either half of the playing area. To score a goal, participants had to dribble the ball across the opponents' backline. The rationale for introducing a different set of rules for game practice was to ensure that all participants approached the game performance test on equal terms.

In total, all participants practiced two 7 ½ minute sessions with a two-minute interval in each practice session. After completing the 15-minute practice session, participants were cleared to leave the experiment area. However, on the final practice session, participants took the acquisition test which was conducted in the same manner as the pre-test. One week after the final practice session, the first retention test was administered. A second retention test was conducted three weeks after the last practice session. The retention test followed the same

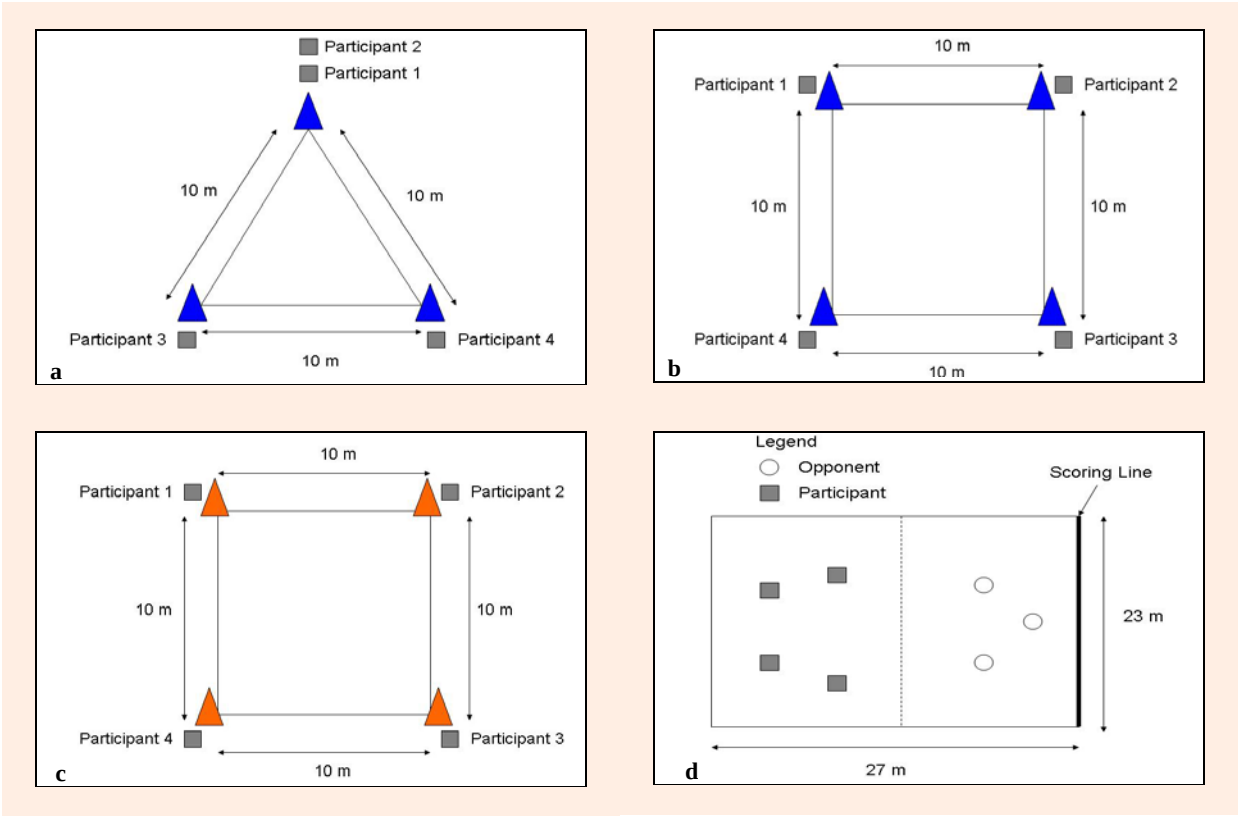

Figure 3. Layout for practice group a) Blocked Station A, b) Blocked Station B, c) Random, d) Game-based.

format as the pre-test for skill performance. A transfer test was also conducted one week after the final practice session. The game performance test took place after the skill performance test and followed the same format as the game performance pre-test.

Statistical analyses

Skill performance scores were analysed using a 3 Groups (blocked, random, game-based groups) x 2 Time period (pre-test, acquisition test) split plot analysis of variance (SPANOVA) for the acquisition phase. Separate t-tests between the pre-test and acquisition test were performed for the groups to follow-up significant scores.

For retention, a 3 Groups (blocked, random, game-based groups) x 2 Tests (retention 1, retention 2) SPANOVA was conducted on the skill performance outcome scores to assess the learning of the dribble and push pass. Follow-up tests were conducted between the groups on overall retention scores for significant effects.

For game performance, the control and execution variables were calculated as percentages of correct responses out of total number of opportunities to respond. A 3 Groups (blocked, random, game-based groups) x 2 Time periods (pre-test, post test) SPANOVA was conducted on the trapping control and the passing, shooting and dribbling execution variables. In addition, a 3 Groups (blocked, random, game-based groups) x 2 Time periods (pre-test, post test) SPANOVA for total number of successes and total number of attempts were conducted as a secondary analysis for game performance.

In all cases, the Bonferroni adjustment was used for the post hoc comparisons and the level of significance for all SPANOVA analyses were set at alpha = 0.05. Strength of association were calculated using generalised omega squared (ω2G) and based on criteria that ω2 = 0.01 is a small association, ω2 = .059 is a medium association and ω2 = 0.138 or larger is a large association (Kirk, 1995). Effect sizes for significant interactions were calculated using Hedges' g and based on criteria that 0.2 is small, 0.5 is medium and 0.8 is large.

Table 2. Means and standard deviations of skill performance scores for dribble speed and push accuracy and speed for each group at pre-test and acquisition.

		Pre-Test		Acquisition Test		Retention 1		Retention 2	
		M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Dribble Speed (seconds)	**Blocked**	4.92	(1.25)	3.83	(0.71)	3.59	(0.67)	3.59	(0.51)
	Random	4.70	(1.16)	3.95	(0.87)	3.60	(0.77)	3.73	(0.82)
	Game-Based	5.01	(1.23)	3.68	(0.77)	3.47	(0.57)	3.55	(0.47)
Push Accuracy (points)	**Blocked**	2.48	(0.93)	3.34	(0.54)	3.36	(0.82)	3.28	(0.84)
	Random	2.58	(0.74)	3.03	(0.56)	3.54	(0.79)	3.70	(0.69)
	Game-Based	2.42	(1.10)	3.16	(0.77)	3.69	(0.69)	3.52	(0.84)
Push Speed (km/h)	**Blocked**	33.90	(7.10)	35.21	(7.06)	33.33	(8.55)	34.36	(6.78)
	Random	34.67	(5.35)	33.73	(6.17)	32.70	(4.73)	31.06	(5.20)
	Game-Based	31.93	(4.57)	38.28	(5.90)	37.44	(6.91)	36.58	(8.02)

Table 3. Means and standard deviations of percentage of successful executions during game performance test for each group at pre-test and post test.

		Pre-Test		Post Test	
		M	*(SD)*	*M*	*(SD)*
Trapping	**Blocked**	67.02	(13.59)	74.68	(12.97)
	Random	63.66	(7.70)	79.14	(3.96)
	Game-Based	65.23	(9.82)	82.73	(7.11)
Passing	**Blocked**	67.95	(15.98)	69.47	(8.25)
	Random	64.58	(10.91)	67.20	(9.84)
	Game-Based	65.73	(15.25)	72.27	(5.89)
Shooting	**Blocked**	65.00	(31.83)	69.45	(18.76)
	Random	50.00	(36.06)	46.02	(21.00)
	Game-Based	79.17	(33.23)	52.20	(33.42)
Dribbling	**Blocked**	92.23	(10.02)	88.98	(7.44)
	Random	98.00	(4.47)	93.22	(4.19)
	Game-Based	86.48	(14.37)	91.80	(4.42)

Table 4. Means and standard deviations of total number of successful attempts during game performance test for each group at pre-test and post test.

		Pre-Test		Post Test	
		M	*(SD)*	*M*	*(SD)*
Trapping	**Blocked**	19.33	(9.56)	20.83	(8.61)
	Random	20.00	(7.91)	17.40	2.51
	Game-Based	18.67	(7.71)	22.17	(2.48)
Passing	**Blocked**	24.00	(9.84)	22.67	(8.36)
	Random	23.00	(9.82)	19.20	(2.59)
	Game-Based	21.67	(5.92)	22.83	(4.40)
Shooting	**Blocked**	1.33	(0.82)	2.50	(1.05)
	Random	1.60	(1.14)	4.00	(2.55)
	Game-Based	1.33	(0.52)	2.67	(2.50)
Dribbling	**Blocked**	8.67	(4.80)	11.17	(2.93)
	Random	9.20	(3.77)	14.60	(3.78)
	Game-Based	7.83	(3.19)	14.67	(3.67)

Table 5. Means and standard deviations of total number of attempts during game performance test for each group at pre-test and post test.

		Pre-Test		Post Test	
		M	*(SD)*	*M*	*(SD)*
Trapping	**Blocked**	28.00	(10.08)	27.50	(8.07)
	Random	31.20	(9.83)	22.00	(3.16)
	Game-Based	27.83	(7.94)	26.83	(2.48)
Passing	**Blocked**	34.67	(8.66)	32.00	(7.69)
	Random	34.80	(9.04)	29.20	(6.57)
	Game-Based	32.83	(5.00)	31.50	(4.97)
Shooting	**Blocked**	2.00	(1.67)	3.67	(1.37)
	Random	3.00	(1.87)	7.00	(1.87)
	Game-Based	2.00	(1.10)	5.17	(3.37)
Dribbling	**Blocked**	8.83	(4.58)	12.83	(4.07)
	Random	9.40	(3.78)	15.60	(3.71)
	Game-Based	9.00	(3.03)	15.67	(3.67)

Results

Skill performance mean scores and standard deviations for each group during pre-test, acquisition and retention tests are presented in Table 2. For game performance, the mean scores and standard deviations for percentage of successful executions, total number of successful executions and total number of attempts during the pre-test and transfer test are presented in Tables 3, 4 and 5, respectively.

Skill performance test

Pre-test

A one-way analysis of variance confirmed that there were no significant between-group differences at the start of the experiment for all three measures (i.e., dribble, push accuracy and speed).

Acquisition

There was a significant main effect for Time for all three measures with significantly poorer scores in the pre-test compared to the acquisition test. (Dribble: $F(1, 65) = 86.26$, $p < .001$, $\omega 2G = .207$; Push Accuracy: $F(1, 65) = 30.18$, $p < .001$, $\omega 2G = .150$; Push Speed: , $F(1, 65) = 10.53$, $p = .002$, $\omega 2G = .02$).

There was no significant main effect for Group for

all three measures. As for the Interaction effect, only the Time x Group interaction for Push Speed was significant, $F(2, 65) = 9.28$, $p < .001$, $\omega 2G = .049$. Follow-up t-test comparisons between the pre-test and acquisition test showed that the game-based group had significantly improved speed performance by the end of the practice phase $t(23) = 5.15$, $p < .001$, $g = 1.18$, 95% CI [.54, 1.82]. The blocked, $t(23) = 1.01$, $p = .32$, and random groups, $t(19) = 1.07$, $p = .30$, did not significantly change over time.

Retention

The analysis revealed that there was no significant Interaction, Time or Group effect for the Dribble and Push Accuracy. For Push Speed, the analysis revealed only a significant main effect for Group, $F(2, 65) = 3.34$, $p = .04$, $\omega 2G = .051$. Comparisons of means indicated that the game-based group had higher push speeds compared to the random group ($p = .04$). There were no differences in learning between the game-based and blocked group ($p = 0.30$) and between the blocked and random group ($p = .94$).

Game performance test

Pre-test

A one-way analysis of variance conducted on the game performance pre-test scores also confirmed that there were no significant between-group differences for trapping, passing, shooting and dribbling.

Percentage of successful executions

There was a significant main effect for Time for trapping and passing execution (Trapping: $F(1, 14) = 15.18$, $p = 002$, $\omega 2G = .261$; Passing: $F(1, 14) = 8.35$, $p = .012$, $\omega 2G = .111$), but not for shooting execution and dribbling control. In addition, there was no significant main effect for Group or for the Group x Time interaction between the group and time variables for the control or execution variables.

Total number of successful executions

The analysis revealed that there were no significant main effects for Group for all control and execution variables. However, a significant main effect for Time was found for shooting execution, ($F(1, 14) = 6.39$, $p = .024$, $\omega 2G = .132$) and dribbling control, $F(1, 14) = 44.07$, $p < .001$, $\omega 2G = .388$), whereby the total number of successful executions for shooting and dribbling increased between the pre and post test scores. Furthermore, a significant interaction effect was also detected for dribbling control , $F(2, 14) = 3.94$, $p = .04$, $\omega 2G = .080$, whereby the game-based training group had a higher number of successful dribbling executions compared to the blocked group in the post test, $t(10) = 2.91$, $p = .015$, $g = 1.55$, 95% CI [.26, 2.84].

Total number of attempts

Only shooting execution, ($F(1, 14) = 14.30$, $p = .002$, $\omega 2G = .238$), and dribbling control, ($F(1, 14) = 64.66$, $p < .001$, $\omega 2G = .396$), yielded significant effects for Time, whereby the post hoc analysis revealed that there were a significantly higher number of total attempts in the post test compared to the pre-test. All other analyses were insignificant.

Discussion

This study examined the effects of practice schedules that was categorised according to both location on the contextual interference continuum and stability of the environment context on the learning of field hockey skills practiced in combination. The primary purpose of this study was to investigate if practicing several sports skills in combination was supported by the contextual interference effect.

Based on the skill performance test, the results showed that in general, all groups improved dribble and push accuracy performance during the acquisition phase. More specifically, the low interference (blocked) and both high interference groups (random and game-based) had performed the close dribble quicker and had pushed the ball more accurately during the acquisition test compared to the pre-test. As for push speed performance, only the game-based participants pushed the ball faster during the acquisition phase. In the retention phase, the results revealed that there were no differences between the high and low interference groups for all the three skills. The game-based training group had pushed the ball faster than the other two groups, perhaps due to the demands of a game, but these differences were not significant.

While these findings are contrary to the typical CI effect of high interference groups showing diminished performance during acquisition and increased performance during retention as compared to low interference groups (Magill and Hall, 1990), other studies using sports skills had similar findings as the current study (e.g., Brady, 1997; Jones and French, 2007; Landin, et al., 2003; Meira and Tani, 2003; Zetou et al., 2007). These studies had used tasks from different motor programs and the skills were practiced in isolation or independent of one another. Several of these studies that did not find differences between groups practicing with different amounts of CI suggested that task complexity was the reason for not displaying the CI effect when practicing several skills that were from different motor programs (Jones and French, 2007; Landin, et al., 2003; Meira and Tani, 2003). Guadagnoli et al. (1999) had reported that the CI effect was more effective in simple skills compared to complex motor skills and sport skills were considered to be complex skills according to Herbert et al. (1996). It is possible that practicing complex tasks made it too difficult for the high interference groups to cope with the intra and inter task demands that are present when skills from different motor programs were practiced together.

Yet, it was still hypothesised that the high interference groups would still display the CI effect even though tasks from different motor programs were used in this study. Unlike previous studies, the hockey skills were practiced in combination in an effort to reduce inter task difficulty by chunking two and three skills as one and to create a functional skill that resembled actual game situations and gave meaning to the tasks. Despite this differ-

ence, it appeared that practicing a combination skill was not effective in reducing the inter task difficulty for the high interference groups to show increased performance in retention or for the low interference group to show increased performance in acquisition. Therefore, these results suggested that whether tasks are practiced in isolation and independently or in combination, the CI effect was not supported.

Using game performance as an indicator of transfer in performance, the results from the test revealed no significant between-group differences in trapping, passing, shooting and dribbling execution, in terms of percentage of successful executions. Collectively, all groups improved their percentage of success on trapping and passing execution. The improvement across time may be explained in that the trapping and passing skill were found in both practice combinations during acquisition. This finding across time is similar to a study on field hockey skills by Turner and Martinek (1992). The authors found a significant increase over time for the control variable (similar to trapping execution in this study) for two experimental groups (i.e., games for understanding and technique instructional), but significant differences between the two treatment groups for game skill execution were not detected.

Secondary analyses on the total number of successful executions and number of attempts were also conducted for the transfer test. More specifically, this was to investigate the failure of detecting improvements in percentage of successful executions in the case of shooting and dribbling execution. Lack of improvements could be caused by decreases in successful executions when number of attempts remained the same or equal ratio increases or decreases in both total number of successful executions and number of attempts. For instance, making two shots at goal with one on target would provide a 50% success rate that is similar to making four shots on goal with two on target. Indeed in a game, it is important to create more opportunities and increase the number of successful shots on goal. For total number of attempts, as expected, there were significantly more attempts to dribble in the playing area and to shoot at goal during transfer. As Turner and Martinek (1992) had suggested, when participants were able to control (trapping execution) the ball better, they were able to create more opportunities to dribble the ball and also to shoot at goal. Similarly, for total number of successful executions, the analysis revealed a large practice effect for advancing and keeping the ball under control while dribbling and that all groups were getting more shots on target. As such, although the percent success analysis did not reveal an improvement in shooting or dribbling among the groups, the higher number of successful dribbles and shots indicated that practice was still beneficial for game performance.

There was some support for the CI effect when total number of successful executions was analysed. There appeared to be one significant between-group difference with a large effect whereby the game-based group was more successful at dribbling without losing control of the ball compared the blocked group in the transfer test. In addition, although not significantly different, it was revealed that both high interference groups had a higher number of successful executions and attempts for shooting and dribbling execution. More specifically, the random and game-based groups had made more shots at goal and were more successful at getting the shots on target compared to the blocked group. The random group had also made more attempts and was more successful at dribbling the ball. These results are encouraging as it shows some support that the CI effect may be evident when performance was assessed in a real-world situation of game performance. This finding is supported in a review by Broadbent et al. (2015b) which concluded that future research directions involving perceptual-cognitive training in relation to the CI effect should include field-based transfer tests as the norm. To date, there are limited number of CI studies that have assessed performance and learning using game playing ability. Brady (1997) tested participants on an 18-hole round of golf and found that the random group were no different from the blocked group. Among other reasons, it was possible that one or two skills had improved for either group but because a composite score for four skills were used, improvements in some skills could not be detected. Another study assessed the acquisition and transfer of perceptual-cognitive skills using a field-based tennis protocol and reported that the CI effect was indeed present (Broadbent et al., 2015a). It is clear that much more research investigating the effects of practice schedule using game performance outcomes are needed to confirm or deny the support for the CI effect involving applied sports skills.

Magill (2011) suggested that when practicing closed skills with inter trial variability or open skills, the practice condition should simulate as many regulatory and non-regulatory conditions so that it resembled the possible scenarios of a game. Yet, evaluation of studies conducted to investigate the CI effect had focused on skills that were practiced with little resemblance to regulatory or non-regulatory conditions that could be experienced in a match. Therefore, the second purpose of this study was to investigate the influence of predictability of the environment on the learning of sport skills under different practice schedules. In a predictable environment, the time to execute a skill is dependent on the individual and the type of skill that is performed is a closed skill. Conversely, open motor skills are performed in an unpredictable environment whereby other people are in motion at the time a skill is being executed by an individual (Knapp, 1977). A game-based training condition represented a random schedule in an unpredictable environment and was compared to a predictable blocked and random protocol in a CI setting.

In a recent study, Broadbent et al. (2015a) had assessed a random group practicing tennis simulation training (similar to an unpredictable environment) and reported increases in transfer of learning compared to the blocked practice group. The results of this study matched Broadbent et al.'s (2015a) finding and was in line with the hypotheses, whereby the game-based group outperformed the blocked and random groups in some measures of the skill acquisition test. At the very least, it matched the performance of the blocked and random group in the

other measures of the skill acquisition test. In addition, it executed skills better than the low interference group in the game performance test. This finding is in support of a review by Gabbett et al. (2009) that found that game-based training (presented in a random and variable practice framework) was no better or worse with a technical skills training (presented in a fixed and blocked practice framework) in terms of skill performance test, but was more superior in a game performance test. The results also add to the limited body of knowledge for long-term learning. The game-based participants of this study maintained their performance at one and three weeks after the acquisition phase and confirms one previous study reviewed in Gabbett et. al. (2009). In a research on Australian football players, the authors found non-significant improvements which were maintained following a three-week retention period.

Conclusion

In conclusion, there is some evidence to show that the CI effect in sports settings is present when CI is assessed similar to real-world situations. In addition, there appeared to be some value of practicing skills randomly in an unpredictable environment. CI studies should explore the use of game-based protocols as a random high interference practice schedule and its influence on the CI effect. Further support for this practice schedule will give more alternatives to coaches in terms of organising the practice sessions.

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Key points

- The contextual interference effect was not supported when practicing several skills in combination when the sports skills were assessed in a closed skill environment.
- There appeared to be some support for the contextual interference effect when sports skills were assessed in an open skill environment, which were similar to a real game situation.
- A game-based training schedule can be used as an alternative practice schedule as it displayed superior learning compared to a blocked practice schedule when assessed by the game performance test (real-world setting). The game-based training schedule also matched the blocked and random practice schedules in the other tests.

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