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ORIGINAL ARTICLE

Learner-adapted practice promotes skill transfer in unskilled adults learning the basketball set shot

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Abstract
The current study used a complex, sport-specific movement skill to explore the effects of a win-shift/lose-stay practice schedule on learning and compared its effectiveness with that of blocked and random practice schedules. Thirty-six adults (24.9 ± 3.3 years) were assigned to blocked, random and learner-adapted training groups. Each participant performed 360 trials of the basketball set shot from multiple locations across six practice sessions. For the learner-adapted group, switching between task variations was performance-contingent; switching between shooting locations occurred only following a successful shot. Shooting success was calculated as the percentage of successful shots performed, and measured during pre-acquisition (i.e. baseline), acquisition (i.e. practice) and post-acquisition (i.e. retention and transfer). Despite scoring less shots throughout practice compared to baseline testing, the learner-adapted group showed a significant improvement for shooting success in transfer ($d = 1.02$). Blocked practice demonstrated significant improvements for shooting success in immediate retention ($d = 1.83$), delayed retention ($d = 1.69$) and transfer ($d = 1.39$). Random practice significantly improved shooting success in both immediate ($d = 1.03$) and delayed retention ($d = 0.81$). The current findings highlight that performance during practice does not necessarily represent the permanency and adaptability of skill learning. The implications of the findings and their practical applications are discussed in the context of practice scheduling during learning of a sports skill.

Keywords: *Skill acquisition, practice, contextual interference, performance, learning, transfer*

Highlights

- Performance and learning are influenced by the order in which skill repetitions are practised.
- Adapting the order of skill repetitions to the learner during practice promoted skill transfer.
- The current findings highlight the importance of measuring skill learning over time.
- Absence of improvement during practice does not necessarily reflect an absence of learning, which may emerge at a later time or under different task constraints.

Introduction

Maximising skill learning in practice settings is a key aim for sports coaches and practitioners (Eliasz, 2011; Hebert, Landin, & Solmon, 1996). One approach shown to influence the rate, permanence and adaptability of movement skill learning is practice scheduling, or the order in which skills are performed (Lee & Simon, 2004; Menayo, Sabido, Fuentes, Moreno, & García, 2010; Shea & Morgan, 1979). On the basis of a wealth of research on contextual interference (CI; Battig, 1979; Shea & Morgan, 1979), a range of practice schedules have been developed, and are implemented, in regular sports practice (e.g. blocked, random, serial etc.). Interestingly, the effects of learner-adapted practice schedules, which change as a result of performance outcomes, are less well understood, particularly within the sporting domain (Lee & Wishart, 2005). The overall aim of the current study was to investigate the effects of a learner-adapted practice schedule on the acquisition, retention and transfer of a complex movement skill and compare these effects with blocked and random practice schedules.

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Traditionally, practice schedule research has used the blocked and random practice dichotomy to explore the differential effects of practice structure on skill development (Hall, Domingues, & Cavazos, 1994; Lee & Simon, 2004; Merbah & Meulemans, 2011). Blocked practice involves completing all trials of a task or task variation before moving onto a different task or task variation, whereas random practice interleaves tasks or task variations in an unpredictable order. When compared to random practice, blocked practice schedules typically produce superior performance during skill practice, but impaired performance on measures of learning (i.e. retention and transfer tests; Brady, 1998). Conversely, when compared to blocked practice, random practice schedules typically produce impaired performance during skill practice, but superior performance on measures of learning (Kantak & Winstein, 2012; Merbah & Meulemans, 2011; Soderstrom & Bjork, 2015). This paradoxical effect of practice scheduling is termed the CI effect (Battig, 1979; Shea & Morgan, 1979) and refers to the "cognitive effort" (Brady, 1998; Farrow & Buszard, 2017; Li & Wright, 2000) or relative amount of difficulty created when two or more tasks or task variations are practiced. Typically, blocked practice provides low CI and random practice provides high CI (Shewokis, Del Rey, & Simpson, 1998), though a number of factors, such as retroactive inhibition, testing order or reminder trials, and multiple retention tests have been shown to influence the CI effect (Del Rey, Liu, & Simpson, 1994; Fairbrother, Shea, & Marzilli, 2007; Shea & Titzer, 1993). See Brady (2008) and Lee and Simon (2004) for a comprehensive discussion of factors influencing the CI effect in movement skills.

It is possible, however, that by focusing exclusively on the extremes of the CI continuum, as with blocked and random practice, alternative practice schedules that promote better learning (i.e. retention and transfer) are overlooked (Landin & Hebert, 1997). To provide more appropriate amounts of CI throughout skill learning, researchers have explored "hybrid" practice schedules where opportunities for error correction are provided through repeated trials of one task variation prior to the interference of another task variation (Merbah & Meulemans, 2011; Proteau, Blandin, Alain, & Dorion, 1994).

Though there appears some support for the effectiveness of hybrid practice schedules in sports skills (see Landin & Hebert, 1997), a limitation of all predetermined practice schedules is that task variations remain fixed regardless of performance changes (Brady, 1998; Magill & Hall, 1990; Simon, Lee, & Cullen, 2008). In line with Guadagnoli and Lee's (2004) challenge point framework, optimal learning may be facilitated further by adapting task difficulty to an individual's skill proficiency or rate of learning. Unlike predetermined schedules, learner-adapted practice schedules use the individual's own performance to determine when to switch between tasks (Simon et al., 2008). It has been suggested that using performance to dictate task variations, both initially and as practice progresses, provides better learning outcomes than predetermined practice schedules due to the continuous manipulation of appropriate levels of task challenge (Choi, Qi, Gordon, & Schweighofer, 2008; Guadagnoli & Lee, 2004). Despite this understanding, very few studies have explored the effects of learner-adapted practice on movement skills (see Choi et al., 2008; Eliasz, 2011; Simon et al., 2008) and none have explored the effect of learner-adapted practice in sport-specific skills.

One particular learner-adapted approach, win-shift/lose-stay (WSLS), uses a criterion measure of success to determine when learners switch tasks (Choi et al., 2008; Simon, Cullen, & Lee, 2002, 2008). In this method, if a participant succeeds at a task they shift to the next task, whereas an unsuccessful attempt results in a further repetition of the original task. Initial investigations of WSLS practice schedules have demonstrated moderate support for gradual increases in CI based on the learner's practice performance (Choi et al., 2008; Eliasz, 2011; Simon et al., 2002, 2008). However, these are limited to simple movement tasks such as computer key pressing (see Eliasz, 2011 and Simon et al., 2008) and visuomotor transformations (see Choi et al., 2008), and are measured via performance error or movement times. To better understand the effects of practice scheduling in applied contexts, it has been proposed that skill acquisition research needs to employ tasks that involve multiple degrees of freedom, greater cognitive engagement, and a higher degree of difficulty (Hebert et al., 1996; Williams & Hodges, 2005; Wulf & Shea, 2002).

It has also been suggested that, within an applied context, transfer tests are the "gold standard" measure of learning and results from transfer tests should take precedence over results from retention tests (Farrow & Buszard, 2017). Assessing the emergence of specific task and environmental constraints, within the context of which the skill is intended to be performed, provides a more representative measure of learning (Farrow & Buszard, 2017; Pinder, Davids, Renshaw, & Araújo, 2011). As such, exploring the effects of the WSLS practice schedule using a sports skill, and using a measure of skill transfer, would improve the generalisability of the CI effect in addition to ascertaining appropriate degrees of task challenge and practice progressions (Farrow & Buszard, 2017).

The aims of the current study were to (i) explore the effects of a learner-adapted practice schedule, WSLS, on the learning (i.e. retention and transfer) of a complex, sport-specific movement skill, and (ii) compare its effectiveness with that of traditional blocked and random practice schedules. The rationale for using a learner-adapted practice schedule was to explore whether tailoring the order of repetitions to an individuals' performance during practice, and thus providing appropriate levels of CI and relative task difficulty, could promote better learning than blocked and/or random practice schedules.

Given that the assigned task challenge would match the individual's relative task difficulty, it was hypothesised that learner-adapted practice would lead to a greater proportion of skill repetitions performed at shooting locations of greater difficulty (i.e. greater distance and angle to basket). As a result, it was predicted that participants engaging in learner-adapted practice would demonstrate poorer performance throughout practice, compared to both blocked and random practice. Finally, it was hypothesised that, due to the tailored approach to practice scheduling, and the task challenge being constantly adapted to the individual's performance, learning (as measured through retention and transfer tests) would be comparable, if not superior to that of blocked and random practice schedules.

Methods

Participants

Thirty-six volunteers (18 males, 18 females) aged 21–34 years (24.9 ± 3.3 years) who had less than two years' basketball playing experience (1.1 ± 1.3 years) and no representative level basketball playing experience, participated in the research. Participants were randomly assigned to one of three practice groups ($n = 12$); blocked, random, or learner-adapted. After being informed of the risks and benefits, participants provided written consent and agreed to undertake no additional shooting practice throughout the duration of the study. The study received institutional ethical approval prior to the collection of data.

Experimental task

The basketball set shot represented a complex skill with multiple degrees of freedom (Covaci & Talaba, 2013; Kozar, Vaughn, Whitfield, Lord, & Dye, 1994), provided a binary measurement for success (goal versus no goal) and allowed a high number of trials to be executed without producing fatigue. Sessions were conducted using equipment and facilities consistent with competition standards outlined by the Fédération Internationale de Basketball (FIBA, 2014a; FIBA, 2014b). Multiple shooting locations were selected based on previous research (Landin & Hebert, 1997) and provided task variability through manipulations of shooting distance and angle to the basket (Figure 1). Task difficulty increased with shot location (i.e. L1 = least difficult and L4 = most difficult), with locations of greater distance and angle to the basket considered to provide greater task challenge.

To maintain task coherence, all participants were instructed to perform a set shot. In order to distinguish the task from other basketball shot types

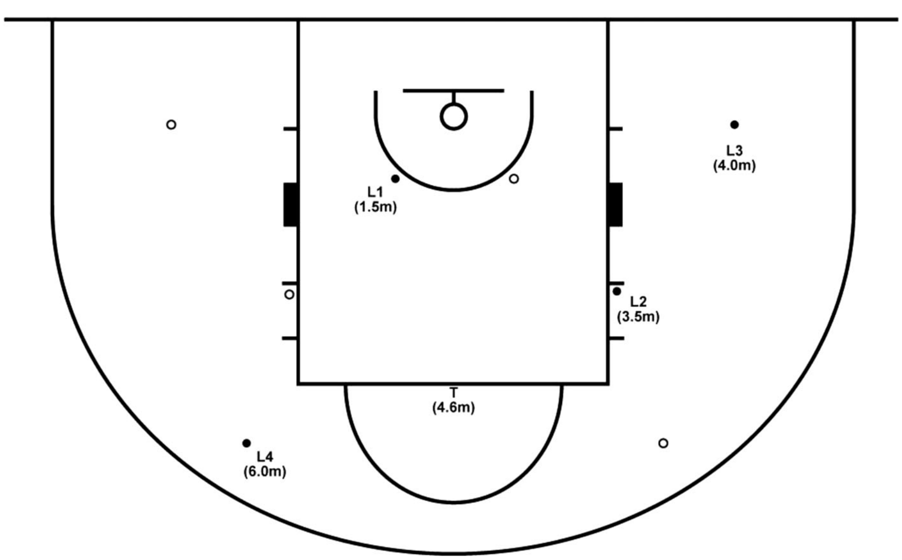

Figure 1. Depiction of task variations (L1-L4 are shooting locations for practice, baseline and retention tests; T is shooting location for the transfer test). Black dots are shot locations for right-handed participants and white dots are shot locations for left-handed participants.

such as the lay up or jump shot, participants were required to execute every shot from a stationary position regardless of distance or angle to the basket. No technical aspects were instructed, measured or assessed, as technical proficiency was not the key aim of the current study, with all shots (i.e. for both practice and tests) recorded as successful or unsuccessful. No feedback was provided to the participants, other than the intrinsic feedback and knowledge of results available to them by performing the task. Following each shot, participants were verbally informed of the location of the next shot.

Experimental design and procedures

In line with similar literature (Choi et al., 2008; Eliasz, 2011; Landin & Hebert, 1997; Simon et al., 2008), the study contained three phases; pre-acquisition, acquisition, and post-acquisition (Figure 2). Research was conducted over a three-week period, with baseline and immediate retention tests during the first and final sessions, respectively, and a 15-minute break separating tests from practice. Six practice sessions were conducted on non-consecutive days during the acquisition phase, with delayed retention and transfer tests seven days post final practice. All groups undertook an identical experimental design, with the only difference being the order in which skills were performed during practice.

Baseline, immediate and delayed retention tests involved 20 trials; five at each shot location following a predetermined quasi-randomised order, with no consecutive trials occurring at the same location (see Appendix 1). The transfer test involved 10 trials from the free throw line, completed in five blocks of two trials each, with a one-minute break between each block. The free throw was considered a transfer test as it reflected the application of the practiced skill to a novel angle and novel distance to the basket.

Practice comprised of 360 trials in total, with 60 trials completed during each of the six practice sessions. Prior to commencing each session, participants were permitted to conduct their own warm-up with or without the basketball, excluding goal shooting. The blocked group undertook 15 trials at one of the four locations before switching to the next, with location order counterbalanced between participants (see Appendix 2). The random group undertook all 60 trials following a predetermined quasi-randomised order, with no consecutive trials occurring at the same location (see Appendix 3). Both the blocked and random groups executed 15 trials at each of the four shooting locations. The learner-adapted group undertook all 60 trials following the same quasi-randomised order as the random group (see Appendix 3), however they only switched shooting locations following a successful trial. Therefore, compared to the blocked and random groups, participants in the learner-adapted group performed a disproportionate number of shots at each of the locations, both per session and in total.

Statistical analyses and dependent variables

The sample size for the current study was guided by the sample sizes and analyses of similar studies, including Hall et al. (1994; $n = 10$), Landin and Hebert (1997; $n = 10$), Landin, Hebert, and Fairweather (1993; $n = 14$), and Simon et al. (2008; $n = 12$). Based on a predicted moderate effect size, using G*Power v.3.19 (Faul, Erdfelder, Lang, & Buchner, 2007) it was determined that a minimum of nine participants was required (Effect size = 0.52, Power = 0.80, $p = .05$). As such, the recruited

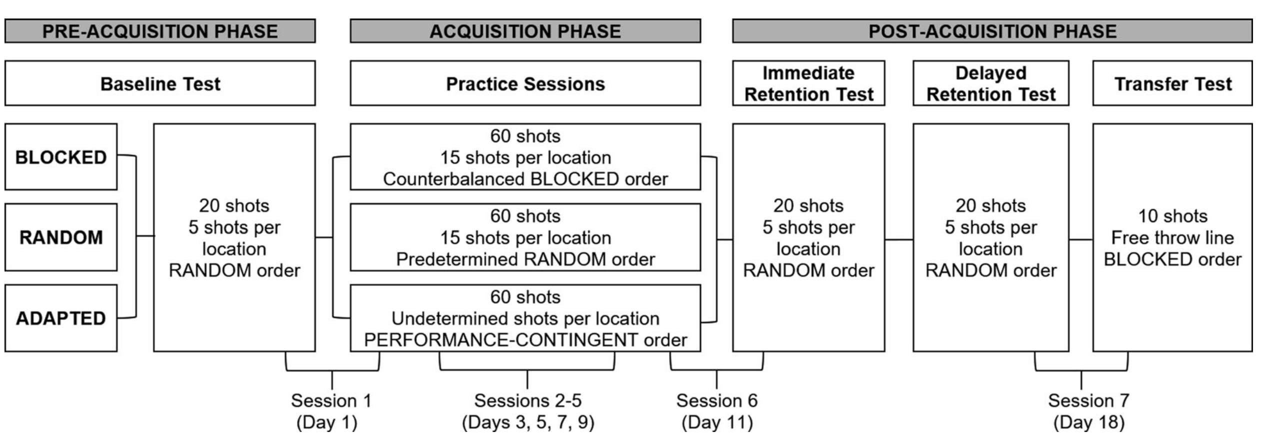

Figure 2. Experimental design and timeline for the three practice groups (blocked, random and learner-adapted) over the three phases (pre-acquisition, acquisition and post-acquisition).

sample of 12 participants was considered appropriate.

Shooting success: Individual scores were averaged per session and presented as a mean group score. To allow comparison between practice and test sessions which had 60 and 20 trials, respectively, shooting success was calculated as a percentage of successful shots to total shots executed for each session. A binary scoring system was chosen to maintain consistency with the scoring system utilised in competition, where goal attempts are either successful or unsuccessful.

To assess the differences between the three practice schedules and shooting success, a two-way analysis of variance was performed with repeated measures on the last factor for retention and transfer (Group × Test) and practice (Group × Practice). Post-hoc analyses were conducted on significant effects and on values which were close to reaching the nominal significance level ($p < .05$), warranting further investigation. To determine the magnitude of difference between shooting scores, partial eta squared (η_p^2) effect sizes were calculated for multiple comparisons (.01, small; .09, moderate; .25, large) and Cohen's *d* effect sizes were calculated for pairwise comparisons (0.5, small; 0.5, moderate; 0.8, large) (Cohen, 1992).

Shooting location: To assess the effect of shooting location on the number of trials executed by the learner-adapted group, analyses of variance was performed with repeated measures on shooting location, and with shooting location entered in order of increasing shot distance (see Figure 1). A planned post-hoc polynomial contrast assessed the type of relationship between shooting location and the number of trials received by the learner-adapted group. To assess whether the learner-adapted group received significantly more or less trials at any given location compared to the blocked and random group, a one-sample t-test was performed, with 90 trials as the test value. Data was analysed using SPSS (Version 17.0 for Windows; SPSS Inc., Chicago, IL) and Bonferroni adjustments were used for all multiple comparisons.

Results

Analysis of variance at baseline revealed no significant differences between the three groups, $F(2,33) = 0.09$, $p = .917$, $\eta_p^2 < .01$, allowing findings to be reasonably attributed to the effects of practice schedule manipulation. The mean group shooting success during the three phases of the experimental design; pre-acquisition, acquisition, and post-acquisition are illustrated in Figure 3.

Skill learning

No significant group x test interaction, $F(10,165) = 1.73$, $p = .078$, $\eta_p^2 = .09$, or group main effect, $F(2,33) = 0.09$, $p = .917$, $\eta_p^2 = .01$, was found,

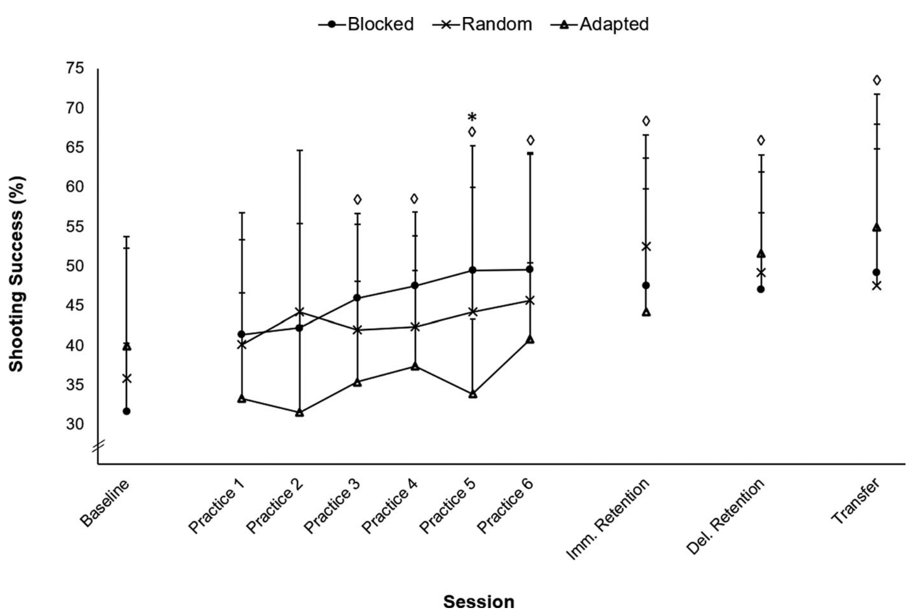

Figure 3. Mean group shooting success for the three practice groups (blocked, random and learner-adapted) across pre-acquisition (baseline), acquisition (practice sessions 1-6) and post-acquisition (retention and transfer tests) phases. Error bars indicate standard deviation. The asterisk indicates a significant between-group difference between the blocked and learner-adapted practice groups ($p < .05$) and the diamonds indicate significant within-group differences ($p < .05$).

indicating that no group performed better than another in retention and/or transfer. There was a significant main effect of test, $F(5,165) = 8.89$, $p < .001$, $\eta_p^2 = .21$, with post hoc analyses revealing significant improvements for all groups.

For the learner-adapted group, a significant improvement compared to baseline was observed in the transfer test ($d = 1.02$), but not in the immediate and delayed retention tests. The blocked group demonstrated significant improvements compared to baseline in the immediate retention ($d = 1.22$), delayed retention ($d = 1.69$) and transfer ($d = 1.39$) tests. The random group demonstrated significant improvements compared to baseline in both the immediate ($d = 1.03$) and delayed retention tests ($d = 0.81$), but not in the transfer test.

Practice performance

There was a significant group x practice interaction, $F(12,198) = 3.97$, $p < .001$, $\eta_p^2 = .19$, with post hoc analyses revealing that the blocked group ($M = 49.44$, $SD = 10.57$) scored significantly more shots than the learner-adapted group ($M = 33.89$, $SD = 9.41$) at practice session 5 (Figure 4). A significant main effect of practice for the blocked group, $F(6,198) = 7.16$, $p < .001$, $\eta_p^2 = .18$, indicated that significantly more shots were scored in practice sessions 3 ($d = 1.47$), 4 ($d = 1.76$), 5 ($d = 1.84$) and 6 ($d = 1.48$). No significant main effect of practice was found for the random or learner-adapted groups, however the learner-adapted group scored less shots compared to baseline for all sessions except practice session 6. No significant main effect of group, $F(2,33) = 1.40$, $p = .261$, $\eta_p^2 = .08$, was found.

Shooting location

Despite the same absolute volume of practice across the three groups (i.e. 360 shots), compared to the blocked and random groups, participants in the learner-adapted group executed a disproportionate number of trials at each shooting location, both per session and in total (Figure 4). Analysis revealed a significant effect of shooting location on the number of trials executed, $F(3,33) = 73.03$, $p < .05$, $\eta_p^2 = .90$. A planned post-hoc polynomial contrast showed a significant linear effect, $F(1,11) = 436.21$, $p < .01$, $\eta_p^2 = .98$, which indicated a positive linear relationship between the number of trials performed by the learner-adapted group and shooting location (i.e. where shooting location was entered in order of increasing shot distance). Participants in the learner-adapted group executed significantly less than 90 shots from the nearer L1 and L2 locations, whilst they executed significantly more than 90 shots from the further L3 and L4 locations (L1: $t(11) = -21.41$, $p < .01$, mean difference $= -44.17$; L2: $t(11) = -8.79$, $p < .01$, mean difference $= -30.92$; L3: $t(11) = 3.22$, $p < .01$, mean difference $= 6.55$; L4: $t(11) = 10.20$, $p < .01$, mean difference $= 66.16$).

Discussion

The current study explored the effects of a learner-adapted practice schedule, WSLS, on skill learning (i.e. retention and transfer) of the basketball set

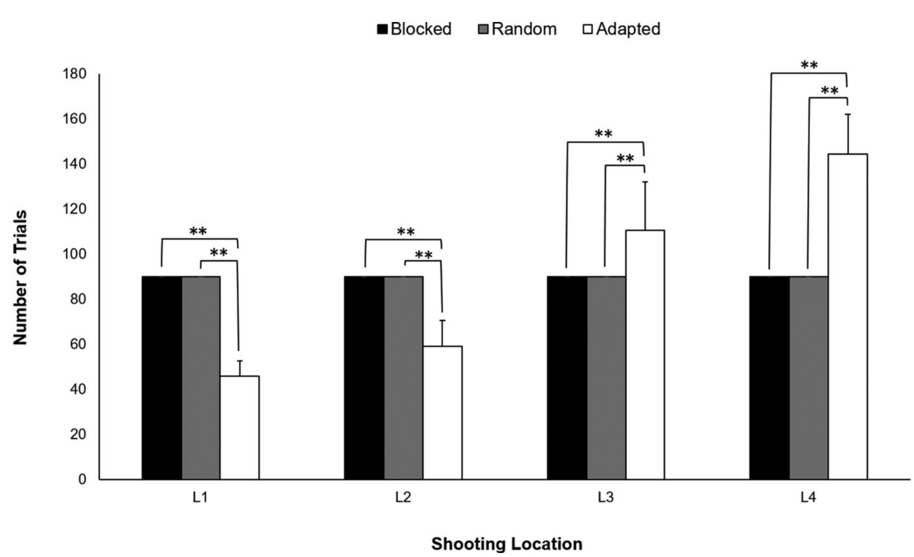

Figure 4. Number of shots performed at each of the four shooting locations (L1-L4) for the three practice groups (blocked, random and learner-adapted) during the acquisition phase (practice sessions 1-6). Error bars indicate standard deviation. Asterisks indicate significant between-group differences ($p < .01$).

shot, and compared its effectiveness with that of traditional blocked and random practice schedules.

Skill learning

It was hypothesised that due to the task challenge being matched to the learners' performance level, and practice being more "individualised" than predetermined schedules, the learner-adapted group would demonstrate superior learning (i.e. retention and transfer) compared to the blocked and random groups. This hypothesis was partially supported; despite the learner-adapted group demonstrating significant improvements in shooting success during transfer, no significant differences compared to the blocked and random groups were observed. The fact that the blocked practice group showed improvements in the retention and transfer tests may have been due to the use of an unskilled cohort. It is possible that the blocked practice schedule provided the unskilled learners the opportunity to explore and establish basic coordinated movement patterns prior to increasing the level of CI via task variability (cf. Gentile, 1972).

Practice performance and shooting location

It was hypothesised that, because task difficulty was constantly matched to the individuals' skill level and rate of learning, learner-adapted practice would result in a greater proportion of shots performed at more difficult locations (i.e. L3 and L4 compared to L1 and L2). This hypothesis was confirmed as the learner-adapted group executed fewer shots at the nearer locations and more shots at the further locations, compared to the blocked and random groups. Subsequent to this, it was anticipated – and confirmed – that the learner-adapted group would score fewer goals throughout practice compared to the blocked and random groups. Interestingly, the learner-adapted group scored fewer goals throughout practice than at baseline and did not return to the pre-acquisition score until the final practice session.

Given this finding, it is possible that the learner-adapted schedule employed in the current study (i.e. WSLS) may have presented an overwhelming increase in CI for the given cohort and did not provide learners sufficient opportunities to engage in, and consolidate, meaningful skill adjustments (Brady, 2008; Landin & Hebert, 1997). As such, an alternative performance contingent schedule, such as switching to the next position following execution of *two* consecutive successful shots, may prove more effective (e.g. more shots scored in retention *and* transfer).

Together, the performance of all groups during practice and on measures of learning (i.e. retention and transfer) highlights that performance during practice does not necessarily represent the permanency and adaptability of skill learning. For example, despite a significant difference in practice performance between the blocked and learner-adapted groups, both groups demonstrated significant improvements in transfer. This suggests that the learner-adapted practice may have promoted a robustness and generalisability of skill improvement which did not emerge until the transfer test, and provided learners the opportunity to explore a variety of movement patterns to differentiate actions and become more functionally adaptive (Davids, Araújo, Hristovski, Passos, & Chow, 2012; Schöllhorn, Mayer-Kress, Newell, & Michelbrink, 2009). Current findings support the argument that the learning of novel movement skills is characterised by errorful executions and an individual's ability to effectively detect and adjust to these are an essential component to skill learning and sports expertise (Lee et al., 2016).

Contextual interference effect

Results of the current study partially support the typical CI effect. Blocked practice demonstrated better performance during practice compared to random practice; however, it also promoted equivalent performance in the retention tests and better performance in the transfer test. Findings are consistent with research using multi-joint skills such as the soccer kick (Li & Lima, 2002), the darts throw (Meira & Tani, 2001) and the golf swing (Goodwin & Meeuwsen, 1996), and may be attributed to the similarity of task constraints (e.g. task variations and length of practice intervention) or individual constraints (e.g. age, expertise, and self-efficacy) used within these studies (Brady, 1998; Hall et al., 1994; Zipp & Gentile, 2010).

Practical implications

The practical implications of the current findings highlight the importance of measuring learning over an extended period of time and adapting the practiced skill to novel contexts. This presents challenges to a coach or practitioner, who after witnessing rapid improvements during practice, may inadvertently assume that an athlete has "mastered a skill", or alternatively, witness a decrease in performance and assume an athlete has "lost a skill" (Farrow, 2008). An athlete's "behavioural potential" (Bakker, Whiting, & Van der Burg, 1990) suggests that an absence of improvement during practice may not necessarily reflect an absence of learning, which may present at a later time. Rather than trying to eliminate error and exploratory behaviours, sports development programmes could value and promote its emergence by guiding the learner through reasonable levels of variability (Handford, Davids, Bennett, & Button, 1997; Turvey & Fitzpatrick, 1993).

Limitations and future research directions

Similar to Goode and Magill's (1986) study using badminton skills and Hebert et al. (1996) study using tennis ground strokes, the limited sensitivity of the scoring employed in the current research may have contributed to a lack of significant between-group findings. This was particularly the case in retention and transfer where differences between groups were smaller and may have required more precise measurements to monitor change. This is reasonable when considering the level of complexity of basketball shooting and may reflect the necessity to measure additional performance outcomes, such as movement kinematics or the use of a more detailed skill-based assessment system (see Landin et al., 1993).

As individual and task constraints have been shown to influence the level of CI present (Hebert et al., 1996), future learner-adapted research may benefit from investigating factors such as age and expertise. Importantly, due to performance decrements during skill learning or delayed emergence of successful performance, as observed within the current study, learner-adapted scheduling may have implications for practice adherence. Psychological constructs such as intrinsic motivation and self-efficacy could provide valuable measures of engagement (see Wulf & Lewthwaite, 2016), with important implications for practice design, particularly over the long term.

Given the limited research exploring learner-adapted practice scheduling, and in particular, studies employing complex movement skills and transfer tests, the results of the current study are preliminary. Further research is required to replicate and strengthen the current findings and their implications, as well as broaden the understanding of learner-adapted practice scheduling within other task and learner constraints such as alternative performance-contingent approaches, expertise level, and discrete versus continuous skills. Further, including a yoked group may provide further insights on whether the participants within the learner adapted group improved due to the practice schedule being tailored to their individual challenge point, or purely because they practiced via a non-fixed practice schedule (e.g. blocked, random, serial, etc.).

In their review on the efficacy of the CI effect in applied sports practice, Farrow and Buszard (2017) addressed the need for CI research to progress transfer of learning measures from traditional retention and transfer tests to assessment within the competition environment, as well as using game-based approaches to practice scheduling (see Cheong, Lay, & Razman, 2016). This highlights an opportunity for future research on the CI effect within complex movement skills to investigate novel practice schedules, whilst maintaining task and environmental relevancy to the context within which they are intended to be applied.

Conclusion

The current study explored the effects of a learner-adapted practice schedule on the learning (i.e. retention and transfer) of the basketball set shot. The understanding of a WSLS paradigm was extended through its application to a complex, sport-specific movement skill. In the current study, adapting the order of skill repetitions to the learner during practice improved the versatility of the skill. Results have important implications regarding practice structure and skill learning within sporting contexts. Specifically, it must be highlighted to sports coaches and practitioners that when using a learner-adapted practice schedule, performance during practice may not always represent the extent or robustness of skill learning. Further research is warranted to confirm whether learner-adapted practice schedules promote better performance and/or learning than traditional practice scheduling methodologies for complex, real-world tasks.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix 1. Order of shooting location for the baseline and retention tests.

NB. All participants completed this test schedule regardless of which practice group they were assigned to.

Trial	Location
1	4
2	2
3	1
4	3
5	1
6	4
7	2
8	3
9	1
10	3
11	4
12	2
13	3
14	4
15	1
16	2
17	1
18	3
19	2
20	4

Appendix 2. Order of shooting location during practice for the blocked group.

NB. Participants in the blocked group completed 15 shots at each of the four shooting locations, with only the order of shot location being counterbalanced. For example, Participant 1 performed 15 shots at location 4, 15 shots at location 3, 15 shots at location 1, and 15 shots at location 2, whereas Participant 2 performed 15 shots at location 2, 15 shots at location 3, 15 shots at location 4 and 15 shots at location 1.

Participant	Location
1	4312
2	2341
3	4213
4	3412
5	4123
6	1342
7	2431
8	3124
9	4231
10	1423
11	2143
12	3241

Appendix 3. Order of shooting location during practice for the random and learner-adapted groups.

NB. All participants within the random group completed this practice schedule. Participants within the learner-adapted group followed the same practice schedule, however only switched shooting location following a successful trial. This resulted in each participant within the learner-adapted practice schedule performing a disproportionate number of trials at each of the locations, both per session and in total.

Trial	Location
1	1
2	4

(*Continued*)

Continued.

Trial	Location
3	3
4	2
5	1
6	2
7	3
8	4
9	3
10	4
11	2
12	1
13	3
14	4
15	1
16	3
17	2
18	4
19	3
20	1
21	3
22	2
23	4
24	1
25	4
26	3
27	2
28	1
29	3
30	1
31	2
32	4
33	3
34	2
35	1
36	4
37	1
38	3
39	4
40	2
41	4
42	3
43	2
44	1
45	4
46	3
47	1
48	2
49	3
50	4
51	1
52	2
53	1
54	2
55	4
56	3
57	4
58	1
59	2
60	3