Effects of Systematically Increasing Contextual Interference on Basketball Players' Skill Performance: A Randomised Controlled Trial

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Abstract

This study is a randomised controlled trial that aims to investigate the impact of different levels of contextual interference (blocked, increasing, and random) on basketball skill performance in male college students. A sample of 106 male college students, who were in good health and had no prior basketball experience, were randomly divided into three groups: blocked schedule (BS), increasing schedule (IS), and random schedule (RS). During a nine-week period, all groups received training in basketball skills, including shooting, dribbling, and passing. Each group adhered to a unique practice schedule. The assessment of skill performance included a pre-test, Post-test 1 (Skill acquisition test), Post-test 2 (Skill retention test), and Post-test 3 (Skill transfer test). The first three tests shared similar content and scoring criteria, while the skill transfer test presented novel challenges. The statistical significance level was defined as $p<0.05$. An initial analysis utilising Mixed-Design Repeated Measure MANOVA indicated significant differences among the three groups in relation to all basketball skill scores ($p < 0.05$). The BS group demonstrated superior performance compared to the IS and RS groups in shooting (FT:17.01±1.52), dribbling (SD:8.39±1.62), and passing (CP:3.60 ±1.01) during the skill acquisition test. However, the IS group demonstrated better performance in shooting (FT:16.26±1.82), dribbling (SD:7.52±0.72), and passing (CP:2.91±0.89) in the skill retention test compared to the BS and RS groups. The results of the one-way MANOVA analysis on post-test 3 indicated that the IS group performed significantly better in the skill transfer test (SS:19.89±2.86, CD:11.25±0.78, and RP:41.86 ±2.84) compared to the BS and RS groups ($p<0.05$). The results indicate that a higher frequency of practice sessions leads to improved basketball skills in beginners, particularly during the skill retention and transfer stages. The IS schedule is an effective method for improving basketball skills.

Keywords: Contextual Interference, Systematically Increasing Schedule, Basketball, Skill Performance.

Introduction

Motor learning encompasses the process of acquiring, honing, and applying motor skills, knowledge, and experience (Haibach-Beach et al., 2023). The main objective is to improve athletes' competitive performance. Practice is widely recognised as the main factor for long-term improvement in motor skills (Guadagnoli & Lee, 2004). Coaches need to have a deep understanding of the complex processes that improve athletic performance in order to achieve success in competitions (Du, 2020). The effectiveness of training methods continues to be a key focus in motor learning, with the optimal practice routine striking a balance between time limitations and achieving rapid progress, long-term retention, and adaptability to different skill requirements (Verwey et al., 2022). Having a deep understanding of the intricacies of practice intensity, type, and structure is crucial for maximising motor skill proficiency (Wright et al., 2016). Coaches and practitioners are always on the lookout for the most effective training methods to enhance players' skill acquisition, retention, and transfer (Williams & Hodges, 2023). Therefore, the contextual interference (CI) effect has attracted considerable interest.

In 1966, Batting introduced the concept of contextual interference in verbal learning. He described it as a form of functional interference that actually improves memory. According to Batting's theory, this effect is a result of learners adapting to different inputs during the learning process (Shumway-Cook et al., 2023). Contextual interference in motor learning refers to the level of interference that arises when practicing multiple tasks concurrently (Aiken & Genter, 2018; Buszard et al., 2017; Graser et al., 2019). Switching

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between tasks or contexts during practice introduces interference that may initially hinder performance but ultimately enhances long-term retention and transfer of skills (Shea & Morgan, 1979). According to Wright et al. (1997), high contextual interference, which involves practicing in a random order, initially results in reduced performance because it requires more cognitive effort per trial. Nevertheless, this increased effort leads to enhanced subsequent performance, as demonstrated by retention and transfer tests (Pauwels et al., 2018). Researchers have investigated a new practice schedule called systematically increasing contextual interference (Porter & Beckerman, 2016; Porter & Magill, 2010). This study investigates the impact of different stages of interference intensity on motor learning. The schedule includes three stages: blocked, serial, and random practice. However, the impact of practicing with gradual increases in contextual interference is still uncertain.

Past research has examined different aspects of contextual interference, such as its impact on gender and age groups (Bortoli et al., 2001; Parab et al., 2018; Pauwels et al., 2015), sports programs (Buszard et al., 2017; Hussen et al., 2020), and experimental settings (Cheong et al., 2016; Tsay et al., 2023). Nevertheless, despite the extensive research conducted, there are still several aspects that have not been thoroughly investigated. Prior research has primarily examined skill acquisition or retention phases, overlooking the critical skill transfer stage (Porter et al., 2020; Rendell et al., 2010), which holds particular significance for elite athletes. The present study investigates the influence of contextual interference on basketball skill performance throughout all stages of motor learning, addressing the existing knowledge gap.

Moreover, there is a lack of research on the impact of systematically increasing contextual interference on motor learning, particularly in relation to tasks governed by distinct motor programs. The investigation of motor learning can be significantly advanced by studying tasks controlled by different Generalised Motor Programs (GMPs) (Ammar et al., 2023). Prior empirical studies have predominantly examined the comparison between blocked and random practice schedules (Kalkhoran & Shariati, 2012; Porter et al., 2020). However, there has been limited investigation into systematically increasing contextual interference (Hussain & Cheong, 2022). Prior studies comparing blocked and random practice schedules have identified inconsistencies and contradictions (Ammar et al., 2023). Examining the impact of increased contextual interference on motor learning is important for improving participants' motor skills through a new practice order.

The development of fundamental basketball skills in the early stages is crucial for mastering complex movement patterns in basketball. According to Jukic et al. (2019), the lack of development of fundamental movement skills in beginners may impede their ability to achieve success in more advanced competitive levels. The practice of fundamental skills is crucial for the long-term growth of athletes or practitioners. This study emphasises the need to examine training methods designed for novice basketball players, specifically those that prioritise fundamental basketball skills.

The contextual interference effect, initially proposed in verbal learning, is highly relevant in motor learning theory. Modifying learners' practice schedules has a direct effect on their performance in skill acquisition, retention, and transfer phases, thus impacting their overall skill development (Wright & Kim, 2019). In the sport of basketball, players are required to choose appropriate skills to either score points or assist their teammates based on the current dynamics of the game. This selection process is influenced by distinct motor programs and the use of technology (Zhang et al., 2019). This study examines the effect of contextual interference on skill performance in basketball learners who practise techniques controlled by diverse motor programs at three stages of learning. This research aims to improve the understanding of the contextual interference effect in basketball training theory.

Literature Review

Contextual interference refers to a type of interference that occurs during learning and is responsible for improving memory. Brady (1998) demonstrated the contextual interference effect, where participants in a low contextual interference schedule showed higher acquisition rates but lower retention and transfer scores. Conversely, participants in a high contextual interference schedule exhibited the opposite pattern. Prior studies have shown that high contextual interference initially impairs performance in skill acquisition tests but improves subsequent performance, especially in retention and transfer tests (Pauwels et al., 2018). The advantage of the contextual interference effect has mainly been observed in controlled laboratory experiments.

In these experiments, inexperienced participants engage in extensive practice repetitions over a short duration to master simple movement tasks (Buszard et al., 2017; Cheong et al., 2016). Nevertheless, the results of field studies have shown inconsistency (Aiken et al., 2018). The effectiveness of practice schedules in motor learning may vary depending on the competitive environment (Buszard et al., 2017). Caution should be exercised when generalising recommendations from laboratory-based research to practitioners regarding optimal practice scheduling methods, due to the differences between laboratory and field settings (Darling-Hammond et al., 2020). This section examines the impact of contextual interference on motor learning and analyses it based on various research conditions.

One can categorize the settings for experiments as either laboratory or field research (Aziz, 2017). In the early 1990s, laboratory experiments provided significant support for the classic contextual interference effect. The most commonly employed tasks include multi-segment movement tasks, propulsive tasks, and coincidence anticipation tasks (Goode & Magill, 1986; Wrisberg & Liu, 1991). However, the existing studies primarily focus on simple tasks, investigating only a few instances of complex tasks (Graser et al., 2019). Laboratory experiments prioritise internal validity at the expense of external validity due to the artificial setting may not accurately represent real-world conditions (Aziz, 2017).

Within applied contexts, scholars primarily examine the general aspects of sports programs, including volleyball skills (Fialho et al., 2006), tennis skills specifically related to serving the ball (Broadbent et al., 2015), and basketball skills (Porter et al., 2020; Zhang, 2014). Furthermore, specific tasks targeting particular populations, such as children and elders, have been investigated. These tasks include dance step sequences and musical instrument playing (Bertollo et al., 2010; Stambaugh, 2011), lifting objects (Duff & Gordon, 2003), beanbag throwing (Jarus & Gutman, 2001), and handwriting skills (Ste-Marie et al., 2004). Graser et al. (2019) found limited to moderate support for the CI effect in various non-laboratory tasks. It is unclear how laboratory or non-laboratory tasks contribute to the CI effect. Field experiments are conducted in real organisational settings and have high internal and external validity. However, conducting such experiments is uncommon due to the challenges involved in manipulating treatments and controlling for extraneous effects in a real-world setting (Aziz, 2017).

Applied settings typically involve specific motor skill training, where tasks can be categorised into either a single generalised motor program (GMP) or multiple generalised motor programs (GMPs) (Czyż, 2021). The golf-putting tasks are representative examples of experimental research controlled by the same DMP as the tasks (Porter et al., 2010). The objective was to propel the golf ball to varying distances. The results suggest that the progressive group had the highest performance during the skill retention phase of the test. In a subsequent study, Saemi et al. (2012) investigated the effects of throwing a ball to three different distances. Participants practiced a total of 81 times. The study's results show that the progressive practice group outperformed the blocked group in the skill retention test, and there was a significant difference between the two groups. Hall et al. (1994) selected 30 college team members as subjects for tasks governed by various GMPs. The experimental task involved learning three baseball skills: fastballs, curveballs, and change-up pitches.

The results indicated no significant difference in skill acquisition test scores between the two groups. However, in the retention test, the random group outperformed the block group significantly. Subsequently, Zetou et al. (2007) chose three volleyball serving skills as tasks, whereas Cheong et al. (2012) chose three hockey skills for practice. The participants selected for the study were inexperienced and came to the same conclusion. The random group and the blocked group demonstrated significant improvement in both the pretest and posttest for the three skills. However, there was no significant difference between the two groups after the intervention, and no significant interaction was observed between the groups and the practice schedule. The tasks governed by various GMPs did not exhibit a typical CI effect. Overall, research examining various tasks controlled by the same or different GMPs in applied settings has yielded inconsistent findings.

The CI effect may interact with the skill level of the practitioner (Ammar et al., 2023) According to Magill and Hall (1990), there is a relationship between high levels of CI and the initial learning phase. The degree of CI, learner experience, and task characteristics can interact to affect the learner's conditions (Guadagnoli et al., 2004). Learners' mastery of experience and skills enhances the learning effect. Higher levels of CI have been found to be advantageous for tasks that are less challenging, while individuals with more expertise tend to exhibit superior learning outcomes compared to novices (Salkowski & Russ, 2018). Prior research has examined the impact of the learner's skill level on the experimental outcomes (Ammar et al., 2023; Czyż & Coker, 2023; Hebert et al., 1996). Experienced practitioners who engaged in high levels of CI demonstrated no detrimental effects on skill acquisition tests and maintained high CI during the retention and transfer phase (Ollis et al., 2005; Rendell et al., 2010). The analysis of the research results indicates a correlation between the learner's experience level and the practice schedule.

Materials and Methods

Participant

This study recruited 106 healthy male first-year college students through an open recruitment process. The participants were then randomly assigned to one of three groups: the Blocked Schedule (BS) group, the Increasing Schedule (IS) group, or the Random Schedule (RS) group. All participants lacked prior basketball experience. Table 1 presents the demographic characteristics and pre-test scores for each group in detail. All participants in the study provided informed consent, and prior to the intervention, the research followed the ethical guidelines of the Universiti Putra Malaysia Research Ethics Committee (Reference number: JKEUPM-2023-722). The results of one-way ANOVA indicated that the three groups showed similar error variances in demographic information and pre-test scores for basketball skills (P>0.05), consistent with the assumption of homogeneity of variances. Prior to the intervention, there were no significant variations in demographic characteristics or basketball proficiency levels among the three groups of participants.

Table 1

Participants' demographic characteristics and pre-test scores in basketball skills

Variables	BS group	IS group	RS group	All participants	F	Sig.
n	35	35	36	106		
Age (year)	18.49±0.82	18.31±0.58	18.31±0.71	18.37±0.71	0.720	0.489
Height (cm)	177.57±5.34	178.06±5.86	178.47±4.17	178.04±5.13	0.270	0.764
Weight (kg)	70.46±9.41	69.03±9.23	69.42±10.43	69.63±9.64	0.203	0.817
FT	11.63±0.91	11.77±0.73	11.78±1.17	-	0.273	0.762
CP	8.06±1.88	7.20±2.13	7.58±2.41	-	1.690	0.190
SD	12.48±0.77	12.31±0.83	12.42±0.56	-	0.375	0.688
SS	6.17±1.67	5.91±1.47	6.33±1.57	-	0.642	0.528
RP	16.49±1.42	16.86±1.77	16.22±1.71	-	1.340	0.266
CD	21.82±0.83	21.16±1.25	22.02±1.59	-	0.643	0.528

Notes: BS=Blocked Schedule, IS=Increasing Schedule, RS= Random Schedule, FT=Free Throw, CP=two-hand Chest Passing, SD=Straight Dribbling, SS=Spot Shooting, RP=two-hand Running Passing, CD=Controlled Dribbling.

Practice Tasks and Experimental Groups

The selected tasks included three essential basketball skills: free throw (FT), two-hand chest passing, and straight dribbling (SD). All participants engaged in basketball skill practice for a duration of nine weeks. The training regimen included three weekly sessions, with each session consisting of 81 trials. These trials were divided into 27 trials per skill, repeated three times. Therefore, the total number of trials per skill by the end of the intervention was 729. The 9-week programme was divided into three parts, each lasting three weeks, to enhance clarity in assigning exercises to different groups. The participants in the Blocked Schedule (BS) group concentrated on a single skill for three-week intervals (e.g., FT in weeks 1-3, CP in weeks 4-6, and SD in weeks 7-9). The Random Schedule (RS) group implemented a varied practice routine, systematically practicing all three skills in a randomised order.

This approach aimed to avoid consecutive trials of the same skill and maintain a balanced practice order among participants. On the other hand, the Increasing Schedule (IS) group implemented a practice schedule that included blocked, serial, and random orders. For the initial three weeks, participants focused on honing their skills in a specific order (e.g., 243 FT trials in week 1). Over the course of the next three weeks, skills were practiced in a sequential manner (e.g., FT, CP, SD, FT, CP, SD...). Participants in the IS group engaged in practice sessions over the last three weeks, where they randomly practiced various skills. Similar to the RS group, they could repeat the same skill for up to two consecutive trials. Further details of the intervention program are depicted in Figure 1

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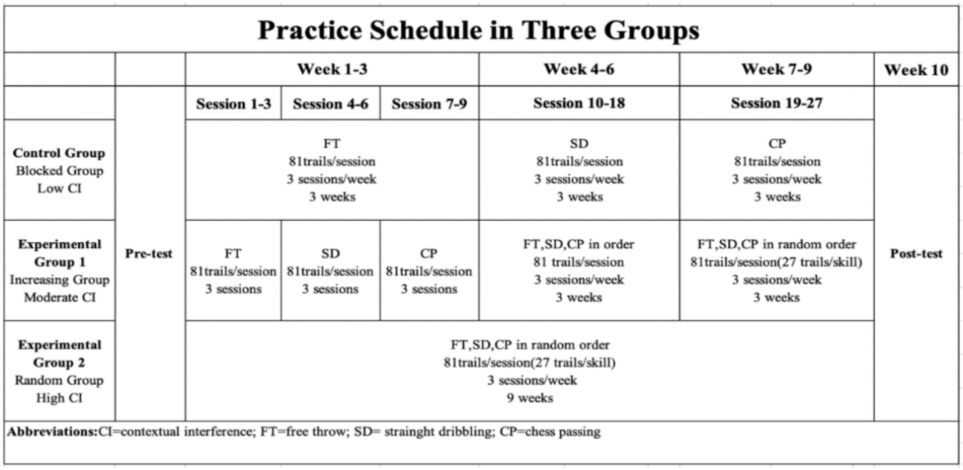

Figure 1: The Details Information of The Intervention Program.

Measurements

This study utilised consistent testing procedures and scoring criteria for the pre-test, post-test 1 (skill acquisition test), and post-test 2 (skill retention test). However, for the third post-test (skill transfer test), we introduced new testing procedures and scoring criteria that are in line with AAHPERD standards. A pre-test was administered to assess the basketball skills of all participants one day prior to the start of the intervention. The scores of each participant were carefully documented.

Skill Acquisition and Retention Test

During the practice and testing sessions for the free throw (FT), participants are challenged to maximise their shot count within a short 60-second timeframe from the free throw line. After each attempt, participants are required to quickly retrieve the ball and take another shot. In terms of scoring, a successful field goal results in 2 points, whereas a missed shot only earns 1 point.

Participants were given instructions to perform a two-hand chest pass from a distance of 5 meters, with the goal of delivering the ball to the central area of the opposite target. The goal was to attain the most minimal score, with the scoring specifics clearly outlined in Figure 2. Participants would be penalised with a lower score if the ball touched a line that divided into two sections on the target. The goal for all participants was to achieve a score of zero with each attempt. The tests were recorded using a camera positioned at a 45-degree angle between the participant and the target area to capture the trajectory of each pass. Video footage was saved directly onto a computer for future analysis. Three impartial observers were assigned the responsibility of assessing all the test videos that were submitted. If a person had trouble determining the exact point of impact on the target, they were told to skip that experiment and move on to the next one.

During the practice and testing of straight dribbling, participants were challenged to use their non-dominant hand to dribble forward, covering a straight distance of 18 meters at maximum speed and returning to the starting point, totalling a distance of 36 meters. A camera was strategically placed to capture the complete movement along the route. It was positioned horizontally, 9 meters along the course and 6 meters away from the dribbling path, ensuring a thorough recording of the entire motion. The dribbling tests were meticulously recorded throughout the entire process. Researchers utilised electronic timers to measure the duration of each test, with the recorded time in seconds serving as the participant's score.

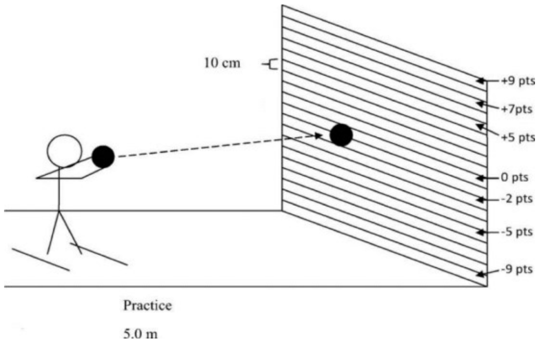

Figure 2: Practice and test process for two-hand chest passing.

Skill Transfer Test

The skills transfer test involved assessing three advanced basketball skills: spot shooting (SS), two-hand running passing (RP), and controlled dribbling (CD). This test evaluated participants' ability to effectively learn and incorporate essential skills.

The spot shooting (SS) test evaluated participants' ability to shoot quickly from various positions, assessing their agility and ball control. The test layout is shown in Figure 3, with five cones indicating shooting positions that are 15 feet away from the basket, which is the same distance as the standard free-throw line. Prior to beginning the test, participants were given instructions to position themselves behind a designated point and start the shooting sequence. After successfully making each shot, participants would collect the ball and proceed to dribble towards the next shooting spot. No dribbling infractions or fouls were allowed. Participants were expected to take a shot from every spot within a strict time limit of 60 seconds. The scoring criteria remained unchanged from previous tests.

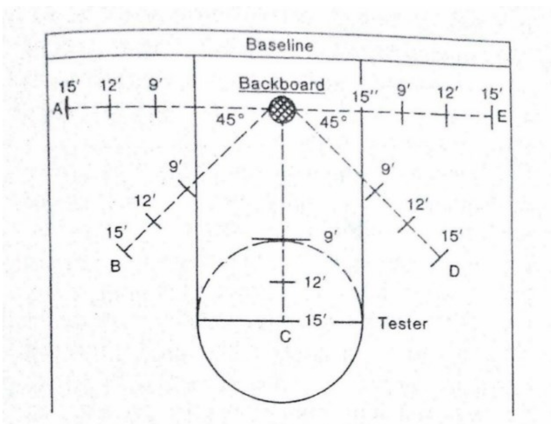

Figure 3: Diagram of Spot Shooting Test.

The two-hand running passing (RP) test, shown in Figure 4, evaluated participants' passing and receiving skills while on the move. The wall is divided into six 2-ft squares, each spaced 2 ft apart, with a restraining line located 8 ft from the wall. Participants positioned themselves behind the training line, directing their attention towards the left target (point A), and grasped a ball. The objective was to complete a two-hand running pass between points A and F within a time limit of 60 seconds. The scoring criteria were as follows: Every accurate pass that hits the target or boundary lines will earn you 2 points, while hitting the spaces between targets will give you 1 point.

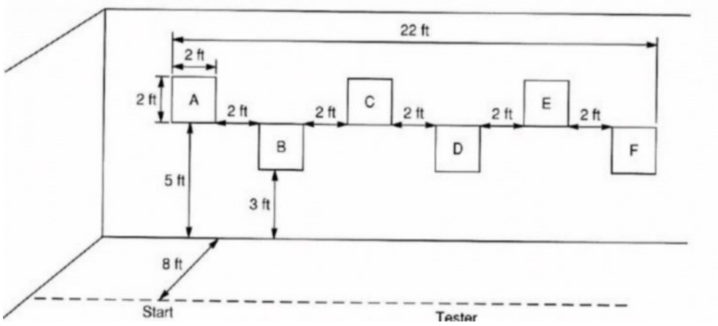

Figure 4: Diagram of Running Passing Test.

The controlled dribbling (CD) test assesses participants' proficiency in dribbling while in motion. Six cones are strategically placed within the free-throw square to act as obstacles. Following the researcher's instructions, the participant starts dribbling using their non-dominant hand, moving from cone A to cone B on the non-dominant side. They follow the designated route using their non-dominant hand until both feet cross the finish line, as shown in Figure 5. Test participants must maintain a consistent hand position throughout the duration of the test. Scoring is determined by the duration it takes to finish the test, measured in seconds.

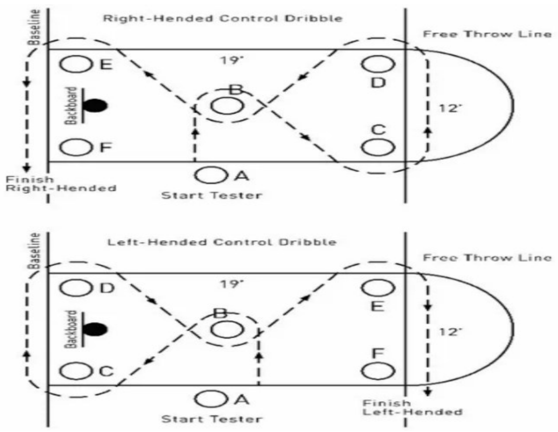

Figure 5: Diagram of Controlled Dribbling Test.

Procedure

The research design used in this study was a Randomised Controlled Trial (RCT), which involved one control group and two intervention groups. This study lasted for a total of ten weeks, with nine weeks focused on the intervention and one week set aside for testing purposes. Participants attended training sessions three times a week, with each session lasting between 60 to 90 minutes. As part of the preparation phase, all participants were given an informed consent form that they needed to sign after thoroughly reviewing it. In addition, they were given an experimental schedule that included detailed information on the experimental procedures, schedule, performance criteria for each basketball skill, warm-up and stretching protocols, and testing procedures. In addition, the test sequence and recovery periods between tests were standardised to ensure consistency during basketball skill testing.

Statistical Analysis

The data were analysed using the Statistical Package for Social Sciences (SPSS) version 26. An analysis was conducted using a Repeated Measures Multivariate Analysis of Variance (MANOVA) to examine the performance of the three skills across the three groups (BS, IS, and RS) and three-time points (pre-test, post-test 1, and post-test 2). In addition, a one-way Multivariate Analysis of Variance (MANOVA) was used to evaluate the performance of skills during the skill transfer phase. Post-hoc comparisons were conducted using the Bonferroni adjustment method. A significance level of 0.05 was chosen.

Results

Table 2 displays the average values (M) and variations (SD) of the initial and final assessments for the three basketball abilities in each group separately. According to the data presented in Table 2, the average scores in post-test 1 for the BS group (FT: 17.01 ±1.52, SD: 8.39 ±1.62, and CP: 3.60 ±1.01) were higher than those of the IS group and the RS group. On the other hand, the IS group had the highest average scores in post-test 2 compared to the BS and RS groups. The scores for FT were 16.26 ±1.82, SD was 7.52 ±0.72, and CP was 2.91±0.89.

Table 2

Means and Standard Deviations of Three Basketball Skills for Separate Groups

Variables		BS group		IS group		RS group	
		M	SD	M	SD	M	SD
FT	Pretest	11.63	0.91	11.77	0.73	11.78	1.17
	Posttest 1	17.01	1.52	15.34	1.94	13.89	1.35
	Posttest 2	14.11	2.11	16.26	1.82	14.75	2.09
SD	Pretest	12.48	0.77	12.31	0.83	12.42	0.56
	Posttest 1	8.39	1.62	9.21	0.99	10.00	1.15
	Posttest 2	9.99	0.78	7.52	0.72	9.22	1.24
CP	Pretest	8.06	1.88	7.20	2.13	7.58	2.41
	Posttest 1	3.60	1.01	4.54	1.42	5.67	1.49
	Posttest 2	4.86	1.57	2.91	0.89	4.06	0.89

Notes: BS=Blocked Schedule, IS=Increasing Schedule, RS= Random Schedule, FT=Free Throw, SD=Straight Dribbling, CP=two-hand Chest Passing.

The results presented in Table 3 demonstrate the results of the Mixed-Design MANOVA with repeated measurements (3 groups x 3 times) for the three basketball skills. Statistical analysis showed significant differences over time for all three basketball skills ($P < 0.001$). In addition, the differences between groups and the relationship between group and time were statistically significant for all basketball skills ($P < 0.001$, respectively). Therefore, the data analysis reveals a noteworthy influence of the 9-week practice under various contextual interference conditions on the three basketball skills among college students, as observed during the baseline, post-test 1, and post-test 2.

Table 3

The Results of Mixed-Design MANOVA with Repeated Measurements within and Between Groups for Three Basketball Skills Variable

Variable	Time		Group		Time * Group	
	F	P value	F	P value	F	P value
FT	315.217	0.000*	6.229	0.003*	10.324	0.000*
SD	947.690	0.000*	11.875	0.000*	35.542	0.000*
CP	406.731	0.000*	4.148	0.019*	3.094	0.000*

Notes: FT=Free Throw, SD=Straight Dribbling, CP=two-hand Chest Passing.

* Indicates significance at $P < 0.05$

The results of the post hoc Bonferroni test, shown in Table 4, highlight the differences in the three basketball skills among the three groups separately. It is worth mentioning that there were noticeable variations among the three groups for each skill between post-test 1 and post-test 2. In the first post-test, the BS group had the highest mean score out of the three groups, surpassing both the IS and RS groups by a significant margin. In addition, the IS group outperformed the RS group with a higher average score. There was a significant improvement in the three basketball skills from the pre-test to post-test 1 within each group. On the other hand, there was a change in the results during post-test 2. The IS group achieved the highest mean score among the three groups, surpassing both the BS and RS groups by a significant margin. In post-test 2, there was a slight difference in the mean scores between the RS group and the BS group. This suggests that there is a notable variation in the three skills at this point.

Table 4

Three Basketball Skills Mean Difference among All Groups in Pre-test, Post-test 1, and Posttest2

Variable	Time	(I) group	(J) group	Mean Difference	STD. Error	P value [a]
FT	Pre-test	RS	IS	0.006	0.227	1.000
			BS	0.149	0.227	1.000
		IS	RS	-0.006	0.227	1.000
			BS	0.143	0.229	1.000

		BS	RS	-0.149	0.227	1.000
			IS	-0.143	0.229	1.000
	Posttest1	RS	IS	-1.454*	0.384	0.001*
			BS	-3.111*	0.384	0.000*
		IS	RS	1.454*	0.384	0.001*
			BS	-1.657*	0.387	0.000*
		BS	RS	3.111*	0.384	0.000*
			IS	1.657*	0.387	0.000*
	Posttest2	RS	IS	-1.507*	0.478	0.006*
			BS	0.636	0.478	0.558
		IS	RS	1.507*	0.478	0.006*
			BS	2.143*	0.481	0.000*
		BS	RS	-0.636	0.478	0.558
			IS	-2.143*	0.481	0.000*
SD	Pretest	RS	IS	0.119	0.173	1.000
			BS	-0.052	0.173	1.000
		IS	RS	-0.119	0.173	1.000
			BS	-0.171	0.174	0.986
		BS	RS	0.052	0.173	1.000
			IS	0.171	0.174	0.986
	Posttest1	RS	IS	0.794*	0.304	0.031*
			BS	1.610*	0.304	0.000*
		IS	RS	-0.794*	0.304	0.031*
			BS	0.816*	0.306	0.027*
		BS	RS	-1.610*	0.304	0.000*
			IS	-0.816*	0.306	0.027*
	Posttest2	RS	IS	1.702*	0.225	0.000*
			BS	-0.766*	0.225	0.003*
		IS	RS	-1.702*	0.225	0.000*
			BS	-2.468*	0.226	0.000*
		BS	RS	0.766*	0.225	0.003*
			IS	2.468*	0.226	0.000*
CP	Pretest	RS	IS	0.383	0.510	1.000
			BS	-0.474	0.510	1.000
		IS	RS	-0.383	0.510	1.000
			BS	-0.857	0.514	0.295
		BS	RS	0.474	0.510	1.000
			IS	0.857	0.514	0..295
	Posttest1	RS	IS	1.124*	0.315	0.002*
			BS	2.067*	0.315	0.000*
		IS	RS	-1.124*	0.315	0.002*
			BS	0.943*	0.317	0.011*
		BS	RS	-2.067*	0.315	0.000*
			IS	-0.943*	0.317	0.011*
	Posttest2	RS	IS	1.141*	0.276	0.000*
			BS	-0.802*	0.276	0.013*
		IS	RS	-1.141*	0.276	0.000*
			BS	-1.943*	0.278	0.000*
		BS	RS	0.802*	0.276	0.013*
			IS	1.943*	0.278	0.000*

Note: BS=Blocked Schedule (Control), RS=Random Schedule, IS=Increasing Schedule, FT=Free Throw, SD=Straight Dribbling, CP=two-hand Chest Passing.*. Indicates significance at $P < 0.05$.

a. Multiple comparison adj.: Bonferroni method.

A One-Way MANOVA was conducted to evaluate the mean scores of three basketball skills on post-test 3 across the three groups. Post-test 3 is a skill transfer test with unique test content and scoring criteria compared to the previous assessments (pre-test, post-test 1, and post-test 2). The results presented in Table 5 indicate that the IS group demonstrated higher proficiency in the three advanced basketball skills when compared to the BS and RS groups.

Table 5

Means and Standard Deviations of Three Basketball Skills for Separate Groups in Post-test 3

Variables	BS group		IS group		RS group	
	M	**SD**	**M**	**SD**	**M**	**SD**
SS	16.83	3.19	19.89	2.86	17.36	2.44
CD	12.20	0.91	11.25	0.78	12.01	0.94
RP	33.49	2.57	41.86	2.84	37.31	1.24

Notes: BS=Blocked Schedule, IS=Increasing Schedule, RS= Random Schedule, SS=Spot Shooting, CD=Controlled Dribbling, RP=two-hand Running Passing.

The results of the One-Way MANOVA analysis for the three basketball skills are presented in Table 6. Statistical analysis found a significant difference among groups for all three skills (P < 0.001). The data analysis reveals a significant difference in the three skills of post-test 3 among the three groups.

Table 6

The Results of One-Way MANOVA Between Groups for Three Skills Variables in Post-test 3

Variables		N	M	SD	F	P
SS	BS Group	35	16.83	3.185	11.600	**<0.001***
	IS Group	35	19.89	2.857		
	RS Group	36	17.36	2.440		
CD	BS Group	35	12.20	0.914	11.657	**<0.001***
	IS Group	35	11.25	0.776		
	RS Group	36	12.01	0.937		
RP	BS Group	35	33.49	2.571	114.579	**<0.001***
	IS Group	35	41.86	2.840		
	RS Group	36	37.31	1.238		

Notes: BS=Blocked Schedule, IS=Increasing Schedule, RS= Random Schedule, SS=Spot Shooting, CD=Controlled Dribbling, RP=two-hand Running Passing. *. Indicates significance at P< 0.05.

Table 7

Three Basketball Skills Mean Difference among All Groups in Post-test 3

Variable	(I) group	(J) group	Mean Difference	STD. Error	P value
SS	RS	IS	-2.525	0.674	0.001*
		BS	0.533	0.674	1.000
	IS	RS	2.525	0.674	0.001*
		BS	3.057	0.679	0.000*
	BS	RS	-0.533	0.674	1.000
		IS	-3.057	0.679	0.000*
CD	RS	IS	0.759	0.208	0.001*
		BS	-0.198	0.208	1.000
	IS	RS	-0.759	0.208	0.001*
		BS	-0.957	0.209	0.000*
	BS	RS	0.198	0.208	1.000
		IS	0.957	0.209	0.000*
RP	RS	IS	-4.552	0.550	0.000*
		BS	3.820	0.550	0.000*
	IS	RS	4.552	0.550	0.000*
		BS	8.371	0.554	0.000*
	BS	RS	-3.820	0.550	0.000*
		IS	-8.371	0.554	0.000*

Notes: BS=Blocked Schedule, IS=Increasing Schedule, RS= Random Schedule, SS=Spot Shooting, CD=Controlled Dribbling, RP=two-hand Running Passing. *. Indicates significance at P< 0.05.

The results presented in Table 7 from the post hoc Bonferroni test revealed significant differences in spot shooting and controlled dribbling between the IS and BS groups, as well as between the IS and RS groups, in post-test 3 (P < 0.001, P = 0.001 < 0.05). However, there was no statistically significant difference observed between the BS and RS groups in relation to these aspects (P = 1.000 > 0.05). A significant difference (P < 0.001) was observed among the three groups in terms of snap passing. The data analysis reveals a significant difference between the IS group and the other two groups in terms of performance in the three skills in post-test 3. Specifically, the IS group students demonstrated significantly better performance compared to the other two groups.

Discussion

The discussion is organised into three subsections, each examining the impact of contextual interference and comparing the three groups across three post-tests: post-test 1 (skill acquisition test), post-test 2 (skill retention test), and post-test 3 (skill transfer test).

A significant difference was found among the three groups in terms of selected basketball skills in the skill acquisition test (p<0.05). The BS group showed the highest performance, while the RS group had the lowest performance in each of the three skills. This finding is consistent with previous studies conducted by Feghhi and Valizade (2011), Porter et al. (2016), Pasand et al. (2016). A study found that after 324 trials of basketball free throw training, the control group, which practiced under a blocked order, performed better than the increasing group and random group in the skill acquisition test (Feghhi et al., 2011). Pasand et al. (2016) found a similar result in their study, where participants practiced three volleyball skills (forearm pass, set, and service) under different schedules. The post-hoc Tukey test revealed a significant difference among the study groups (F=5.18, p < 0.001), with the blocked group showing a higher preference compared to the increasing and random groups. Hebert et al. (1996) proposed that random practice schedules are less effective for beginners in acquiring new skills, suggesting that novices should use a blocked practice schedule instead (Raisbeck et al., 2015). According to Gentile (1972) and Siedentop (1980), beginners should spend sufficient time exploring and developing basic movement patterns, overcoming proficiency barriers, and experiencing power transformations before moving on to random practice. In addition, the number of skills taught simultaneously must be taken into consideration, in addition to the practice schedule. Teaching a young or novice learner too many skills in one session can cause overwhelm (Brady, 2004)

The retention test results are essential for evaluating the long-term durability of skill enhancement (Sattelmayer et al., 2016). The results of our study indicate that the increasing schedule group performed the best in the retention test, while the blocked group had the lowest performance. The pattern remained consistent across shooting, dribbling, and passing skills. This finding is supported by studies conducted by Porter et al. (2016). In experiment 2 conducted by Porter and Magill, the impact of increasing practice schedule on tasks controlled by different generalised motor programs was investigated. Participants were assigned to practice three distinct basketball passes (chest, overhead, single arm) under blocked, random, or increasing schedules. The study by Porter et al. (2010) found that participants who practiced with gradually increasing contextual interference performed better in retention tests compared to those who practiced under blocked or random scheduling. Porter et al. (2016) conducted a study on visuomotor learning in a rotary pursuit tracking task. They manipulated the level of contextual interference by varying the revolutions per minute (RPM) on a rotary pursuit tracker. Porter et al. (2016) found that all three groups showed performance improvement during practice, as indicated by statistical analysis. The results of the post-test analysis showed that the increasing group performed better than the blocked and random groups in the retention test.

This study intentionally selected novel test content and scoring criteria for the skills transfer test. The objective was to reproduce the shooting, dribbling, and passing abilities employed in a real competitive context. Pinder et al. (2011) argue that assessing skills during competition allows us to determine if the learning obtained from specific tasks and environmental conditions during practice is applicable to real-world competitive situations. The study's findings indicate that the increasing schedule group demonstrated the highest performance in the transfer test for shooting, dribbling, and passing skills individually. This finding supports the conclusions made by Hajihosseini (2016). In order to further investigate the CI effect, researchers compared the systematically increased practice schedule with the conventional blocked and random schedules. They specifically examined learning tasks that were controlled by the same generalised motor program (GMP) (golf putting tasks) and different GMPs (three distinct basketball passes) separately (Porter et al., 2016). The results of these experiments indicate that a practice schedule that includes systematic increases in contextual interference improves skills acquisition. Hajihosseini (2016) investigated the potential benefits of systematically increasing CI levels during practice to improve shooting skill retention and transfer. The study found that participants who practiced with gradual increases in CI performed better on retention and transfer tests compared to those who followed traditional blocked scheduling (Hajihosseini, 2016).

Conclusion

Overall, research consistently shows that increasing and random practice schedules lead to better retention and transfer performance, despite initial delays in skill acquisition compared to blocked practice. Furthermore, a systematic increase in contextual interference has been found to be more effective in improving learners' retention or transfer test performance compared to random practice alone.

After carefully analysing the performance of the blocked and random groups, an interesting finding came to light: the random group showed slightly better performance than the blocked group. This discovery is consistent with the theory of contextual interference (CI) effect. In behavioural studies, it has been suggested that practice schedules with less repetition, such as random practice, require greater cognitive effort compared to more repetitive practice structures like constant practice (Lelis-Torres et al., 2017). The hypotheses highlight the growing need for memory processes linked to practice schedules that are less repetitive (Lelis-Torres et al., 2017). Likewise, empirical evidence backs the idea that increased contextual interference imposes substantial cognitive processing demands (Buszard et al., 2017). In contrast to blocked practice, where the learner repeats multiple trials of a single skill before progressing to the next set of trials, random practice introduces the learner to different variations with each trial (Gill et al., 2018).

Shewokis and Snow highlighted the importance of transfer tests in assessing the contextual interference effect (Ammar et al., 2023), emphasising their reliability. According to Brady (2004), Magill pointed out that transfer tests are more effective at evaluating adaptability, in contrast to retention tests which mainly focus on measuring learning outcomes. Thus, while there may be some similarities between retention and transfer, they are considered separate but interconnected concepts. Considering this, the findings obtained from transfer testing should carry more weight in comparison to those from retention testing (Buszard et al., 2017). Transfer testing assesses the ability to perform skills in different conditions or when the task is modified. Regardless of the test conducted, skill transfer measurements, particularly in competitive scenarios, are recommended to serve as the "gold standard" for assessing learning (Pinder et al., 2011).

Practical Application

Previous studies have provided strong evidence for the positive effects of variable practice (VP) conditions on the consolidation and generalisation of motor memory (Thürer et al., 2019). The impact of this phenomenon becomes especially evident when tasks are controlled by distinct Generalised Motor Programs (GMPs), highlighting the importance of the contextual interference (CI) effect (Ammar et al., 2023). As a result, the results of this study offer hope for individuals involved in basketball, including learners, coaches, researchers, and managers who are looking to improve basketball skills performance through more efficient training methods. In addition, this study highlights the effectiveness of a methodically increasing practice schedule in improving learners' performance during the retention and transfer phases of basic basketball skills. It may be worth considering for coaches, researchers, and managers to implement more frequent training programs across different basketball skills training sessions. In addition, the clear benefit of the variable practice model in motor learning, as demonstrated by previous studies, is further elucidated by the findings of this study. As a result, it is possible that the growing practice schedule could be applied to other sports programs, considering the common stages and principles of motor learning in various athletic endeavours.

Limitation and Further Directions

While this study has thoroughly examined the details of its design and execution, it is important to acknowledge any potential limitations, as is customary in academic research. Firstly, there was a constraint on the instrument in this study. The precision of the ball passing is a crucial factor in evaluating the proficiency of basketball players. A cutting-edge method involves the utilisation of multiple high-speed cameras to accurately capture the precise landing point of the ball. Nevertheless, high-speed cameras come with a hefty price tag and require complex installation, which hinders their widespread adoption. In this study, the researcher utilised the identical testing and scoring methods employed in previous studies. In addition, the research project faced constraints in objective factors, such as funding, which made it challenging to establish consistent dietary arrangements for the participants. However, it is worth noting that the three groups of participants in this study were all from the northern part of China and had similar diets. Nevertheless, the coach recommended that the participants maintain their regular nutritional habits throughout the intervention, and the participants willingly agreed when they signed the consent form. The coach regularly checked in on the students' diet to make sure they were sticking to it.

Several recommendations for possible future research are listed based on the findings. Additional research is required to explore the impact of varying gender, basketball skills, and motor programs on the effectiveness of increased practice schedules. This will help validate the findings obtained so far. Evaluating abilities during a competition provides a way to determine if the knowledge gained from practicing specific tasks and dealing with different conditions carries over to the competitive setting (Pinder et al., 2011). However, the utilisation of such measures has been infrequent in contextual interference literature. Future research should continue to consider the representativeness of the practice context and the increased complexity of the skills.

Data availability statement

The original contributions outlined in the study are incorporated within the article/Supplementary Material. For additional inquiries, please contact the corresponding author directly.

Ethics statement

The human studies conducted in this research were approved by the Universiti Putra Malaysia Research Ethics Committee (Reference number: JKEUPM-2023-722) and were carried out in compliance with local legislation and institutional protocols. Prior to their involvement, all participants provided written informed consent to participate in the study.

Conflict of interest

The authors affirm that the research was conducted without any commercial or financial affiliations that might lead to a perceived conflict of interest.

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References

Aiken, C. A., & Genter, A. M. (2018). The effects of blocked and random practice on the learning of three variations of the golf chip shot. *International Journal of Performance Analysis in Sport, 18*(2), 339-349. https://doi.org/10.1080/24748668.2018.1475199

Ammar, A., Trabelsi, K., Boujelbane, M. A., Boukhris, O., Glenn, J. M., Chtourou, H., & Schöllhorn, W. I. (2023). The myth of contextual interference learning benefit in sports practice: A systematic review and meta-analysis. *Educational Research Review, 39*, 100537. https://doi.org/10.1016/j.edurev.2023.100537

Aziz, H. (2017). Comparison between Field Research and Controlled Laboratory Research. *Archives of Clinical and Biomedical Research, 1*(2), 101-104. https://doi.org/10.26502/acbr.50170011

Bertollo, M., Berchicci, M., Carraro, A., Comani, S., & Robazza, C. (2010). Blocked and Random Practice Organization in the Learning of Rhythmic Dance Step Sequences. *Perceptual and Motor Skills, 110*(1), 77-84. https://doi.org/10.2466/pms.110.1.77-84

Bortoli, L., Spagolla, G., & Robazza, C. (2001). Variability Effects on Retention of a Motor Skill in Elementary School Children. *Perceptual and Motor Skills, 93*(1), 51-63. https://doi.org/10.2466/pms.2001.93.1.51

Brady, F. (1998). A Theoretical and Empirical Review of the Contextual Interference Effect and the Learning of Motor Skills. *Quest, 50*(3), 266-293. https://doi.org/10.1080/00336297.1998.10484285

Brady, F. (2004). Contextual interference: a meta-analytic study. *Percept Mot Skills, 99*(1), 116-126. https://doi.org/10.2466/pms.99.1.116-126

Broadbent, D. P., Causer, J., Ford, P. R., & Williams, A. M. (2015). Contextual interference effect on perceptual-cognitive skills training. *Medicine and science in sports and exercise, 47*(6), 1243-1250. https://doi.org/10.1249/mss.0000000000000530

Buszard, T., Reid, M., Krause, L., Kovalchik, S., & Farrow, D. (2017). Quantifying Contextual Interference and Its Effect on Skill Transfer in Skilled Youth Tennis Players [Original Research]. *Frontiers in Psychology, 8*. https://doi.org/10.3389/fpsyg.2017.01931

Cheong, J. P., Lay, B., Grove, J. R., Medic, N., & Razman, R. (2012). Practicing field hockey skills along the contextual interference continuum: a comparison of five practice schedules. *Journal of Sports Science, 11*(2), 304-311. https://www.proquest.com/openview/b60ec9ab2c10bc4e5933024618bb33f0

Cheong, J. P. G., Lay, B., & Razman, R. (2016). Investigating the Contextual Interference Effect Using Combination Sports Skills in Open and Closed Skill Environments. *Journal of Sports Science and Medicine, 15*(1), 167-175. https://www.jssm.org/hf.php?id=jssm-15-167.xml

Czyż, S. H. (2021). Variability of practice, information processing, and decision making—how much do we know? *Frontiers in Psychology, 12*, 639131. https://doi.org/10.3389/fpsyg.2021.639131

Czyż, S. H., & Coker, C. A. (2023). An applied model for using variability in practice. *International Journal of Sports Science & Coaching, 18*(5), 1692-1701. https://doi.org/10.1177/17479541231159473

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

Du, D. Y. F. (2020). Review of tennis tactics at home and abroad in the last decade. . *Shandong Sports Science & Technology, 42(05), 17-22, 42*(5), 17-22.

Duff, S. V., & Gordon, A. M. (2003). Learning of grasp control in children with hemiplegic cerebral palsy. *Developmental Medicine & Child Neurology, 45*(11), 746-757. https://doi.org/10.1017/S0012162203001397

Feghhi, I., & Valizade, R. (2011). Systematically Increasing Contextual Interference is Beneficial For Learning Single Task. *Procedia - Social and Behavioral Sciences, 30*, 2191-2193. https://doi.org/10.1016/j.sbspro.2011.10.425

Fialho, J. V., Benda, R., & Ugrinowitsch, H. (2006). The contextual interference effect in a serve skill acquisition with experienced volleyball players. *Journal of Human Movement Studies, 50*(1), 65-77. https://www.researchgate.net/publication/286750070

Gentile, A. M. (1972). A Working Model of Skill Acquisition with Application to Teaching. *Quest, 17*(1), 3-23. https://doi.org/10.1080/00336297.1972.10519717

Gill, S. V., Pu, X., Woo, N., & Kim, D. (2018). The effects of practice schedules on the process of motor adaptation. *J Musculoskelet Neuronal Interact, 18*(4), 419-426. https://www.ismni.org/jmni/pdf/74/jmni_18_419.pdf

Goode, S., & Magill, R. A. (1986). Contextual Interference Effects in Learning Three Badminton Serves. *Research Quarterly for Exercise and Sport, 57*(4), 308-314. https://doi.org/10.1080/02701367.1986.10608091

Graser, J. V., Bastiaenen, C. H., & van Hedel, H. J. (2019). The role of the practice order: a systematic review about contextual interference in children. *PloS one, 14*(1), e0209979. https://doi.org/10.1371/journal.pone.0209979

Guadagnoli, M. A., & Lee, T. D. (2004). Challenge Point: A Framework for Conceptualizing the Effects of Various Practice Conditions in Motor Learning. *Journal of Motor Behavior, 36*(2), 212-224. https://doi.org/10.3200/JMBR.36.2.212-224

Haibach-Beach, P. S., Perreault, M. E., Brian, A., & Collier, D. H. (2023). *Motor learning and development*. Human kinetics. https://us.humankinetics.com/products/motor-learning-and-development-3rd-edition-hkpropel-access

Hajihosseini, S. (2016). The effect of moderate contextual interference on motor-skill learning. *Biology and Medicine, 8*(7). https://doi.org/10.4172/0974-8369.1000339

Hall, K. G., Domingues, D. A., & Cavazos, R. (1994). Contextual Interference Effects with Skilled Baseball Players. *Perceptual and Motor Skills, 78*(3), 835-841. https://doi.org/10.1177/003151259407800331

Hebert, E. P., Landin, D., & Solmon, M. A. (1996). Practice Schedule Effects on the Performance and Learning of Low- and High-Skilled Students: An Applied Study. *Research Quarterly for Exercise and Sport, 67*(1), 52-58. https://doi.org/10.1080/02701367.1996.10607925

Hussain, B., & Cheong, J. P. G. (2022). Improving gross motor skills of children through traditional games skills practiced along the contextual interference continuum. *Frontiers in Psychology, 13*, 986403. https://doi.org/10.3389/fpsyg.2022.986403

Hussen, E., Yirga, B., & Aychiluhim, W. (2020). The Effects of Twelve Weeks Technical Training to Improve Basic Skills of Basketball. *Ann Yoga Phys Ther, 4*(1), 1042. https://www.researchgate.net/profile/Wondiye-Aychiluhim/publication/357811561

Jarus, T., & Gutman, T. (2001). Effects of Cognitive Processes and Task Complexity on Acquisition, Retention, and Transfer of Motor Skills. *Canadian Journal of Occupational Therapy, 68*(5), 280-289. https://doi.org/10.1177/000841740106800504

Jukic, I., Prnjak, K., Zoellner, A., Tufano, J. J., Sekulic, D., & Salaj, S. (2019). The Importance of Fundamental Motor Skills in Identifying Differences in Performance Levels of U10 Soccer Players. *Sports, 7*(7). https://doi.org/10.3390/sports7070178

Kalkhoran, A. F., & Shariati, A. (2012). The effects of contextual interference on learning volleyball motor skills. *Journal of Physical Education and Sport, 12*(4), 550. https://doi.org/10.7752/jpes.2012.04081

Lelis-Torres, N., Ugrinowitsch, H., Apolinário-Souza, T., Benda, R., & Lage, G. (2017). Task engagement and mental workload involved in variation and repetition of a motor skill. *Scientific Reports, 7*(1), 14764. https://doi.org/10.1038/s41598-017-15343-3

Magill, R. A., & Hall, K. G. (1990). A review of the contextual interference effect in motor skill acquisition. *Human Movement Science, 9*(3), 241-289. https://doi.org/10.1016/0167-9457(90)90005-X

Ollis, S., Button, C., & Fairweather, M. (2005). The influence of professional expertise and task complexity upon the potency of the contextual interference effect. *Acta Psychologica, 118*(3), 229-244. https://doi.org/10.1016/j.actpsy.2004.08.003

Parab, S., Bose, M., & Ganesan, S. (2018). Influence of Random and Blocked Practice Schedules on Motor Learning in Children Aged 6–12 Years. *Critical Reviews in Physical and Rehabilitation Medicine, 30.* https://doi.org/10.1615/CritRevPhysRehabilMed.2018027737

Pasand, F., Fooladiyanzadeh, H., & Nazemzadegan, G. (2016). The Effect of Gradual Increase in Contextual Interference on Acquisition, Retention and Transfer of Volleyball Skills. *International Journal of Kinesiology & Sports Science, 4*, 72-77. https://doi.org/10.7575/aiac.ijkss.v.4n.2p.72

Pauwels, L., Chalavi, S., Gooijers, J., Maes, C., Albouy, G., Sunaert, S., & Swinnen, S. P. (2018). Challenge to Promote Change: The Neural Basis of the Contextual Interference Effect in Young and Older Adults. *The Journal of Neuroscience, 38*(13), 3333. https://doi.org/10.1523/JNEUROSCI.2640-17.2018

Pauwels, L., Vancleef, K., Swinnen, S. P., & Beets, I. A. (2015). Challenge to promote change: both young and older adults benefit from contextual interference. *Frontiers in Aging Neuroscience, 7*, 157. https://doi.org/10.3389/fnagi.2015.00157

Pinder, R. A., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport and Exercise Psychology, 33*(1), 146-155. https://doi.org/10.1123/jsep.33.1.146

Porter, C., Greenwood, D., Panchuk, D., & Pepping, G.-J. (2020). Learner-adapted practice promotes skill transfer in unskilled adults learning the basketball set shot. *European Journal of Sport Science, 20*(1), 61-71. https://doi.org/10.1080/17461391.2019.1611931

Porter, J., & Beckerman, T. (2016). Practicing with gradual increases in contextual interference enhances visuomotor learning. *Kinesiology, 48*, 244-250. https://doi.org/10.26582/k.48.2.5

Porter, J. M., & Magill, R. A. (2010). Systematically increasing contextual interference is beneficial for learning sport skills. *Journal of Sports Sciences, 28*(12), 1277-1285. https://doi.org/10.1080/02640414.2010.502946

Raisbeck, L., Regal, A., Diekfuss, J., Rhea, C., & Ward, P. (2015). Influence of practice schedules and attention on skill development and retention. *Human Movement Science, 43.* https://doi.org/10.1016/j.humov.2015.07.004

Rendell, M. A., Masters, R. S. W., Farrow, D., & Morris, T. (2010). An Implicit Basis for the Retention Benefits of Random Practice. *Journal of Motor Behavior, 43*(1), 1-13. https://doi.org/10.1080/00222895.2010.530304

Saemi, E., Porter, J. M., Ghotbi Varzaneh, A., Zarghami, M., & Shafinia, P. (2012). Practicing along the contextual interference continuum: A comparison of three practice schedules in an elementary physical education setting. *Kinesiology, 44*(2.), 191-198. https://hrcak.srce.hr/94557

Salkowski, L. R., & Russ, R. (2018). Cognitive processing differences of experts and novices when correlating anatomy and cross-sectional imaging. *J Med Imaging (Bellingham), 5*(3), 031411. https://doi.org/10.1117/1.Jmi.5.3.031411

Sattelmayer, K., Elsig, S., Hilfiker, R., & Baer, G. (2016). A systematic review and meta-analysis of selected motor learning principles in physiotherapy and medical education. *BMC Medical Education, 16.* https://doi.org/10.1186/s12909-016-0538-z

Shea, J. B., & Morgan, R. L. (1979). Contextual interference effects on the acquisition, retention, and transfer of a motor skill. *Journal of Experimental psychology: Human Learning and memory, 5*(2), 179-187. https://doi.org/10.1037/0278-7393.5.2.179

Shumway-Cook, A., Woollacott, M. H., Rachwani, J., & Santamaria, V. (2023). *Motor Control: Translating Research into Clinical Practice*. Wolters Kluwer Health. https://touroscholar.touro.edu/nymc_fac_pubs/4647

Siedentop, D. (1980). *Physical education: Introductory analysis*. Stanford. https://searchworks.stanford.edu/view/900676

Stambaugh, L. A. (2011). When Repetition Isn't the Best Practice Strategy: Effects of Blocked and Random Practice Schedules. *Journal of Research in Music Education, 58*(4), 368-383. https://doi.org/10.1177/0022429410385945

Ste-Marie, D., Clark, S., Findlay, L., & Latimer, A. (2004). High Levels of Contextual Interference Enhance Handwriting Skill Acquisition. *Journal of Motor Behavior, 36*, 115-126. https://doi.org/10.3200/JMBR.36.1.115-126

Thürer, B., Gedemer, S., Focke, A., & Stein, T. (2019). Contextual interference effect is independent of retroactive inhibition but variable practice is not always beneficial. *Frontiers in Human Neuroscience, 13*, 165. https://doi.org/10.3389/fnhum.2019.00165

Tsay, J. S., Irving, C., & Ivry, R. B. (2023). Signatures of contextual interference in implicit sensorimotor adaptation. *Proceedings of the Royal Society B, 290*(1993), 20222491. https://doi.org/10.1098/rspb.2022.2491

Verwey, W. B., Wright, D. L., & Immink, M. A. (2022). A multi-representation approach to the contextual interference effect:

effects of sequence length and practice. *Psychological Research, 86*(4), 1310-1331. https://doi.org/10.1007/s00426-021-01543-0

Williams, A. M., & Hodges, N. J. (2023). Effective practice and instruction: A skill acquisition framework for excellence. *Journal of Sports Sciences, 41*(9), 833-849. https://doi.org/10.1080/02640414.2023.2240630

Wright, D., & Kim, T. (2019). Contextual interference. In (pp. 99-118). https://doi.org/10.4324/9781351189750-6

Wright, D., Verwey, W., Buchanen, J., Chen, J., Rhee, J., & Immink, M. (2016). Consolidating behavioral and neurophysiologic findings to explain the influence of contextual interference during motor sequence learning. *Psychonomic Bulletin & Review, 23*(1), 1-21. https://doi.org/10.3758/s13423-015-0887-3

Wright, D. L., Li, Y., & Coady, W. (1997). Cognitive Processes Related to Contextual Interference and Observational Learning: A Replication of Blandin, Proteau, and Alain (1994). *Research Quarterly for Exercise and Sport, 68*(1), 106-109. https://doi.org/10.1080/02701367.1997.10608872

Wrisberg, C. A., & Liu, Z. (1991). The Effect of Contextual Variety on the Practice, Retention, and Transfer of an Applied Motor Skill. *Research Quarterly for Exercise and Sport, 62*(4), 406-412. https://doi.org/10.1080/02701367.1991.10607541

Zhang, S. L., Lorenzo, A., Zhou, C. J., Cui, Y. X., Goncalves, B., & Gomez, M. A. (2019). Performance profiles and opposition interaction during game-play in elite basketball: evidences from National Basketball Association [Article]. *International Journal of Performance Analysis in Sport, 19*(1), 28-48. https://doi.org/10.1080/24748668.2018.1555738

Zhang, X. (2014). Different Contextual Interference of Children Motor Learning:The Perspective of Same Motor Program Task. . *Journal of Tianjin University of Sport, 29*(3), 247-254.