THE EFFECT OF BLOCKED AND RANDOM PRACTICE SCHEDULE VARIATIONS ON ACQUISITION AND RETENTION OF A PATTERN DRAWING TASK.

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Abstract

The contextual interference (CI) effect refers to the phenomenon that practice organised according to a random schedule appears to negatively affect acquisition, while retention performance is facilitated. Previous research has investigated different combinations of blocked and random practice in order to maximise retention performance. Shea, Morgan, and Ho (1981) indicated that the total amount of random trials in acquisition, not where random trials are interpolated into acquisition was the key to increased retention when performing movement patterns. In contrast, Goode and Wei (1987) suggested that blocked trials followed by random trials were important to the facilitation of learning an open motor skill. The purpose of this study was to examine the effect of blocked and random practice schedule variations on acquisition and retention of a computer-based pattern drawing task. In the first experiment, 48 right-handed participants practiced drawing three different movement patterns using a four-button mouse and a digitising tablet. The participants were given 72 acquisition trials in one of the four groups: blocked, random, random-blocked, and blocked-random. Following the acquisition phase, retention tests of 10 minutes and 24 hours were given to all subjects in a random schedule. The results revealed that although the blocked followed by random practice schedule did not have a significantly superior retention performance, the participants performed equally in retention to those in the random-blocked, and random only groups. The amount of random trials in acquisition did not determine retention performance for a pattern drawing task as the blocked-random and random-blocked groups had half as many random trials as the random only group, but had equal retention performance. In experiment two, different ratios of blocked practice followed by random practice were examined to determine the most effective ratio of blocked-random trials for retention of a computer-based pattern drawing task. Participants practised drawing the same patterns from the previous experiment in one of the three groups: blocked-random low (BR-L), blocked-random medium (BR-M), and blocked-random high (BR-H). The BR-L group had the smallest ratio of blocked trials in comparison to random trials (i.e., 1:5), the BR-H group had the highest ratio of blocked trials in comparison to random trials (i.e., 1:1), and the BR-M group had a mid ratio (i.e., 1:2). The results indicated a Block and a Retention main effect for MT. The MT became faster from Block one to Block 6 across the acquisition session and also became faster from the immediate to delayed retention test. The ordinal relationship revealed the BR-M group had the fastest MT and highest percentage of correctly completed trials in retention, although the relationship was not significant. Implications of the findings are discussed and modifications for future research are identified.

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Introduction

Maximising competition performance is a major concern for current coaches. Manipulating practice schedules is one strategy coaches use to optimise game day performance. To make practice most productive, as soon as the athlete is capable, the skill should be practised in contest-like conditions (Martens, 1990; Martin & Lumsden, 1987). Thus, coaches often schedule practice to focus on acquiring a single skill before that skill is incorporated into a more complex competitive situation. This commonly used practice progression runs contrary to the theoretical prediction that highly accurate practice performance is not advantageous to learning.

Motor Learning Defined

According to Schmidt (1988), "motor learning is a set of processes associated with practice or experience leading to relatively permanent changes in the capability for responding" (p. 346). Four distinct characteristics were included in Schmidt's definition of motor learning. First, learning is a process. The set of internal processes refers to the information processing occurring at different stages of skill development, that together lead to change in behaviour.

Second, motor learning occurs as a direct outcome of practice or experience. Practice or experiences provide the learner with the necessary events for information processing to take place. A major concern for coaches is manipulation of the practice sessions in order to maximise the appropriate processing steps necessary for motor learning.

Third, learning is a relatively permanent change in the capability for performance.

Learning is a lasting occurrence as the motor actions necessary for performance are stored in memory. Changes in performance arising from altered "high" moods or drugs often vanish when the temporary effect of the mood "wears off". These changes in behaviour cannot be attributed to motor learning, as they are not relatively permanent.

Fourth, learning cannot be observed directly. The processes underlying the changes in the capability to perform are internal and are not directly observable. Actual performance does not denote learning. Learning must then be inferred from changes in performance. Transfer[1] or retention[2] tests are used to infer learning as they allow the experimenter to directly observe if performance changes persist after a period of no practice. If the performance change persists after a period of no practice the change is inferred to be relatively permanent, thus implying learning has taken place.

Three questions, which surround learning, stem from a behaviourist view of learning: (1) what is learned, (2) what is the nature of the stimulus, and (3) under what conditions does learning take place? The question of under what conditions does learning take place has received experimental attention with the study of the effect of different practice schedules on motor skill acquisition. Coaches are concerned with practice schedules in order to optimise game day performance.

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[1]Transfer tests examine either the performance of a skill different than the skill that was practised or the practised skill in a different context from the practice situation (Magill, 1993).

[2] Retention tests examine a practised skill following a time interval after practice has ceased (Magill, 1993).

Contextual Interference Effect

An inverse relationship between practice performance and long term retention and transfer performance has been demonstrated to be a result of interference within the practice schedule (see Magill & Hall, 1990 for a review). Predictably, successful practice performances should result in the greatest learning for motor skills as illustrated by successful retention performances. However, highly accurate practice performances have generally been shown to be relatively unfavourable to learning. In contrast, poor practice performances resulting from difficult practice conditions generally led to an increased retention/transfer performance that indicates a learning effect. This inverse relationship between acquisition performance and retention performance is called the contextual interference (CI) effect.

Contextual Interference

The concept of a practice interference effect was introduced and then formalised into the CI effect in the verbal learning research by Battig (1966, 1979). The CI effect identifies interference resulting from practising a task within the context of the practice situation (Battig, 1966, 1972, 1979). Interference arising from a practice context may be either of an intratask or an intertask nature. Intratask interference also known as within-task interference results from practising highly similar tasks. Manipulating the similarity level of items to be practised from low to high increases CI. For example, Battig (1966) manipulated semantic similarity through the use of CCC trigram lists. Learning trigram lists high in semantic similarity; e.g., DWG (DOG), CHT (CAT), HRS (HORSE), produced greater interference during acquisition than trigram lists in which the semantics were categorically dissimilar; e.g., FRG (FROG), TBL (TABLE), CRT (CART). Accordingly a group of highly similar tasks creates more intratask interference within a practice situation then a group of dissimilar tasks. Higher levels of intratask interference results in poor practice performance, but lead to a greater facilitation of retention accuracy for task variations.

Intertask interference also known as between-task interference results from the contextual variety within a practice situation. Contextual variety refers to the presentation schedule of the tasks to be practised. Having the learner practice only one skill in a blocked order during a practice session will establish a low degree of intertask interference. For example, using letters to describe the trial arrangement in a blocked schedule would appear as follows: A-A-A . . ., B-B-B . . ., C-C-C . . .. In contrast, high intertask interference results from practising several different but related skills in random order. The interference results from the unpredictable and constantly changing random practice schedule arrangement that insures variety from trial to trial (e.g., B-A-B-C-B-C-A-C . . .).

Together intratask and intertask interference contribute to the CI effect (Battig, 1979). In his investigation of the facilitative effect associated with list manipulations Battig (1966) observed that a high degree of intratask interference, due to high levels of item similarity in a list, resulted in an associated inter-list facilitation. Battig concluded that intratask interference led to intertask facilitation. In addition, practice schedules high in intertask interference or contextual variety (i.e., random schedule) facilitated task retention. Although the low CI schedule (i.e., blocked) resulted in superior practice performance in comparison to the high CI schedule (i.e., random), the high CI schedule had an increased retention performance.

Learning Motor Skills

Shea and Morgan (1979) conducted the first demonstration of the CI effect in the motor domain. Participants were required to perform three different movement patterns. The movement goal was to grasp a tennis ball and move an arm though a series of small wooden barriers as rapidly as possible. Participants practised the task variations in an acquisition schedule with either a low or high degree of CI. Having the athletes practice each task variation in a blocked order created the acquisition schedule low in CI. In contrast, practising several tasks in random order during the same session created an acquisition schedule high in CI. Although the low CI schedule resulted in superior acquisition performance, the high CI schedule led to increased retention performance. Therefore, as retention tests indicate a relatively permanent change in behaviour from which learning can be inferred, high CI practice conditions lead to better skill acquisition.

Explanations of the Effect

Presently, there are two contending theoretical explanations that account for the cognitive processing underlying the CI effect. One, the elaboration view, also known as the levels of processing hypothesis, was proposed by Craik and Lockhart (1972) and supported by Battig (1972, 1979; Battig & Shea, 1980) and Shea and Zimny (1983). The other, the action plan reconstruction view, otherwise known as the forgetting hypothesis, is founded in the work of Jacoby (1978; Cuddy & Jacoby, 1982) and is supported by Lee and Magill (1983).

Elaboration benefit explanation. The elaboration viewpoint contends that elaborations of the action plan memorial representation occur because of inter-trial variety indicative of a random acquisition schedule. Random practice enables the participant to compare and contrast task variations within working memory[3] and this increased elaboration leads to a more distinctive memory representation of each task variation. During random practice, the elaboration and variability of encoding task variations leads to an increase in different memory access routes. Thus, the greater variety of access routes to the distinct memory representation result in increased retention performance (Craik & Lockhart, 1972). The inter-trial variety requires the learner to process the new task variation along with previous task variations resulting in deeper processing.

Action plan reconstruction view. According to the forgetting hypothesis, the action plan for the task variations must be partially or completely forgotten from working memory in order for increased elaborate processing to occur. During random practice two or more motor programs are used concurrently. This trial to trial variety results in the action plan being forgotten from working memory. Increased processing occurs in the random schedule when the action plan for the forgotten motor program is reconstructed. Therefore, random practice leads to increased retention because of the increased processing due to action plan

[3]Working Memory operates as a system to temporarily store and use just presented information. It provides a temporary workspace to integrate just presented information with information retrieved from long-term memory. It serves as a processing centre to allow problem solving, decision making, and response execution (Magill, 1993).

reconstruction. When identical motor skills are performed consecutively, as in the blocked acquisition schedule, reconstruction of the action plan is not required. For example, if an individual is required to add the numbers 37 + 16 + 15 and then is promptly requested to complete the same math problem over again (i.e., similar to a blocked acquisition schedule) the individual will most likely remember and repeat the answer rather than re-add the numbers. The action plan remains in working memory during a blocked schedule and is effortless to retrieve, thus leading to decreased retention. If several different lists of numbers to be added are presented in succession, the addition would probably have to be performed again as the solution would have been forgotten. The demand for reconstruction requires increased processing and enhances memory representations of all motor programs used during practice.

Both theoretical explanations successfully account for the superior retention performance of a random acquisition schedule over a blocked acquisition schedule. However, the two theoretical hypotheses contrast in their prediction of how task similarity may alter the level of interference (Gabriele, Hall, & Lee, 1989; Lee & Magill, 1983, 1985; Wood & Ging, 1990). The current study does not distinguish between the theories, therefore an explanation of the contrasting predictions of task similarity on CI is in Appendix A.

Practice Schedule Manipulations

The influence of prior related experience on the CI effect was investigated by Del Rey, Wughalter, and Whitehurst (1982). Participants with and without prior experience in open skills were tested on a Bassin Anticipation Timer task. The anticipation timer tested coincident anticipation timing tasks created to model actual open skills. Successfully timing a baseball swing to make contact with a pitch is an example of a coincident anticipation timing task that is characteristic of open skills. Their results demonstrated that experienced participants who practised the tasks in a random or high CI schedule performed significantly better on retention and transfer tests than novice participants in the same acquisition context. Del Rey et al. suggested that novice learners could not gain the same benefit from high CI as experienced learners.

In order to discover how practitioners can effectively apply the CI effect in the classroom, Goode and Wei (1987) investigated different acquisition schedules on beginners learning an open motor skill. The authors tested the performance of different timing tasks on a Bassin Anticipation Timer. The timing task variations were practised in six different acquisition schedules conditions. The six acquisition schedule conditions that consisted of a variety of blocked and random combinations were: (1) random (R), (2) blocked (B), (3) random-blocked (RB), (4) blocked-random (BR), (5) random-blocked-random (RBR), and (6) blocked-random-blocked (BRB). BR and BRB were the two possible combinations of blocking acquisition and then randomising. The RB, RBR, random-only, and blocked-only groups served as comparison groups.

The BR and BRB groups produced the least amount of error in retention, thus indicating that random acquisition did not facilitate the learning of an open skill for a beginner. Higher retention performance was best realised when randomised acquisition trials were practised immediately after blocked acquisition trials. Goode and Wei (1987) suggested that the results of the random group indicate high CI cannot be extended to beginners who have not established a related stable skill pattern. The blocked acquisition schedules helped to establish the necessary action plan, and then after establishing an action plan it was possible to benefit from a random acquisition schedule.

Shea, Kohl, and Indermill (1990) also support the notion that random scheduling benefits may not appear until after the participant acquires the essential movement patterning. Shea et al. (1990) used a rapid force production task to investigate the impact of increasing the amount of both blocked and random acquisition trials on retention. The results indicated the benefits of blocked practice occur early in acquisition, whereas the benefits of random practice happen after initial practice. In contrast, the theoretical perspective by Shea, Morgan, and Ho (1981, as cited in Shea & Zimny 1983), and Shea and Zimny (1983) attest that any random practice should result in better retention no matter when it is interpolated into an acquisition schedule.

Shea et al. (1981, as cited in Shea & Zimny 1983) investigated the effect of interpolating random practice into a blocked acquisition schedule. Shea et al. examined if practising in a blocked schedule first followed by a random schedule would benefit learning. Participants were required to learn a closed skill that consisted of three movement patterns for a bar knock down simulation task. Participants practised the three movement patterns in one of the six conditions: (1) blocked, (2) random, (3) blocked-random (half blocked followed by half random), (4) random-blocked (half random followed by half blocked), (5) mixed condition (alternating blocked and random acquisition sequences over six blocks of trials), (6) mixed condition similar to condition five. The blocked group had faster times during acquisition than the other five groups, which did not differ significantly. During retention tests the random group had the fastest performance time and the blocked group had the slowest performance time. The retention performance for the different blocked and random combination conditions were not significantly different and all had a poorer retention performance than the random group. Shea et al. suggested that the point of CI interpolation might not be a major determinant of retention performance. The different blocked and random combination groups, regardless of the combination, received half the number of randomised (i.e., high CI) trials as the random only group. The increased retention performance of the random group indicates that the amount of random trials in an acquisition schedule is more important to facilitate retention than different blocked and random combination schedules. The important element of retention is that random practice be used in the structure of the learning environment.

Statement of Problem

The results from Shea et al. (1981, as cited in Shea & Zimny, 1983) indicated that an acquisition schedule with blocked trials followed by random trials had the same effect on retention performance as an acquisition schedule with random trials first followed by blocked trials. Shea et al. suggested that the point at which random trials are interpolated into an acquisition schedule is not a determinant of retention performance. According to Shea et al., the total number of random trials in comparison to blocked trials determines the retention performance. In contrast, the results from Goode and Wei's (1987) investigation indicated an acquisition schedule with blocked trials followed by random trials increased retention performance in comparison to an acquisition schedule of random trials followed by blocked trials. The acquisition schedule consisting of blocked trials followed by random trials may have increased retention performance as the scheduling facilitated the necessary environment for early versus late learning.

The primary purpose of this study was to investigate the effect of blocking trials before randomising trials. This study consisted of two experiments. The first experiment sought to establish both the contextual interference effect and a positive blocked before random combination acquisition schedule effect for a computer-based pattern drawing task. The second experiment investigated the effect different ratios of blocked before random practice had on the retention of a computer-based pattern drawing task.

Based upon previous research (i.e., Goode & Wei, 1987), the blocked-random combination acquisition schedule should facilitate the CI effect. In addition, the latest findings (e.g., Shea et al., 1990) suggest that the acquisition condition with the lowest amount of blocked trials followed by the greatest amount of random acquisition trials will best facilitate retention. The initial practice period incorporating low CI will allow the learner to understand and establish an appropriate movement pattern. The subsequent randomised trials will then facilitate the necessary processing for increased retention to occur.

Experiment 1

The effect of blocked and random practice schedules variations on the acquisition and retention of motor skills has been investigated on two occasions. Both investigations incorporated different tasks and resulted in contrasting findings. The first investigation by Shea, Morgan and Ho (1981, as cited in Shea & Zimny 1983) used an arm bar knock down simulation task, but with touch sensitive disks for their participants to learn three different movement patterns. The results from Shea et al. indicated that a practice schedule with blocked trials before random trials had the same effect on retention performance as a practice schedule with random trials first followed by blocked trials.

In contrast, Goode and Wei (1987) used a Bassin Anticipation Timer for their participants to learn three different speeds. The results from Goode and Wei's investigation indicated that a practice schedule with blocked trials before random trials increased retention performance in comparison to a practice schedule of random trials followed by blocked trials.

The purpose of this experiment was twofold. First, this investigation sought to establish the contextual interference effect for a computer-based pattern drawing task. Second, this investigation sought to establish an increased retention performance of a blocked before random combination acquisition schedule as compared to either a blocked, random, or random before blocked combination acquisition schedule for a computer-based pattern drawing task.

Method

Participants

Forty-eight right-handed students and faculty from Lakehead University served as participants on a volunteer basis. None of the participants were colour-blind. Participants were naive to the purpose of the study.[4]

Apparatus and Task

Participants were required to use a SummaSketch III Professional 12" by 18" digitising tablet, a four-button mouse, and a 486 DX/66 personal computer to draw three different predetermined patterns as quickly and accurately as possible. Each pattern consisted of three line segments. Each pattern was paired with a different colour stimulus. Stimulus colours were red, blue, and green (see Figure 1 for pattern tasks). Participants drew a pattern by moving the mouse across the digitising tablet as quickly and accurately as possible.

Eight targets were mounted on the digitising tablet under a transparent covering, (see figure 1 for target configuration). The target configuration mounted on the digitising tablet was directly proportional to the eight targets that remained on the monitor. The lower left target served as the home target from which all movement patterns began.

[4]In retention, seven participants, three from the B group, and two each from the R and RB groups, correctly completed only one trial. There is no variability with one trial result; therefore the data from these participants were removed from the acquisition and retention statistical analyses.

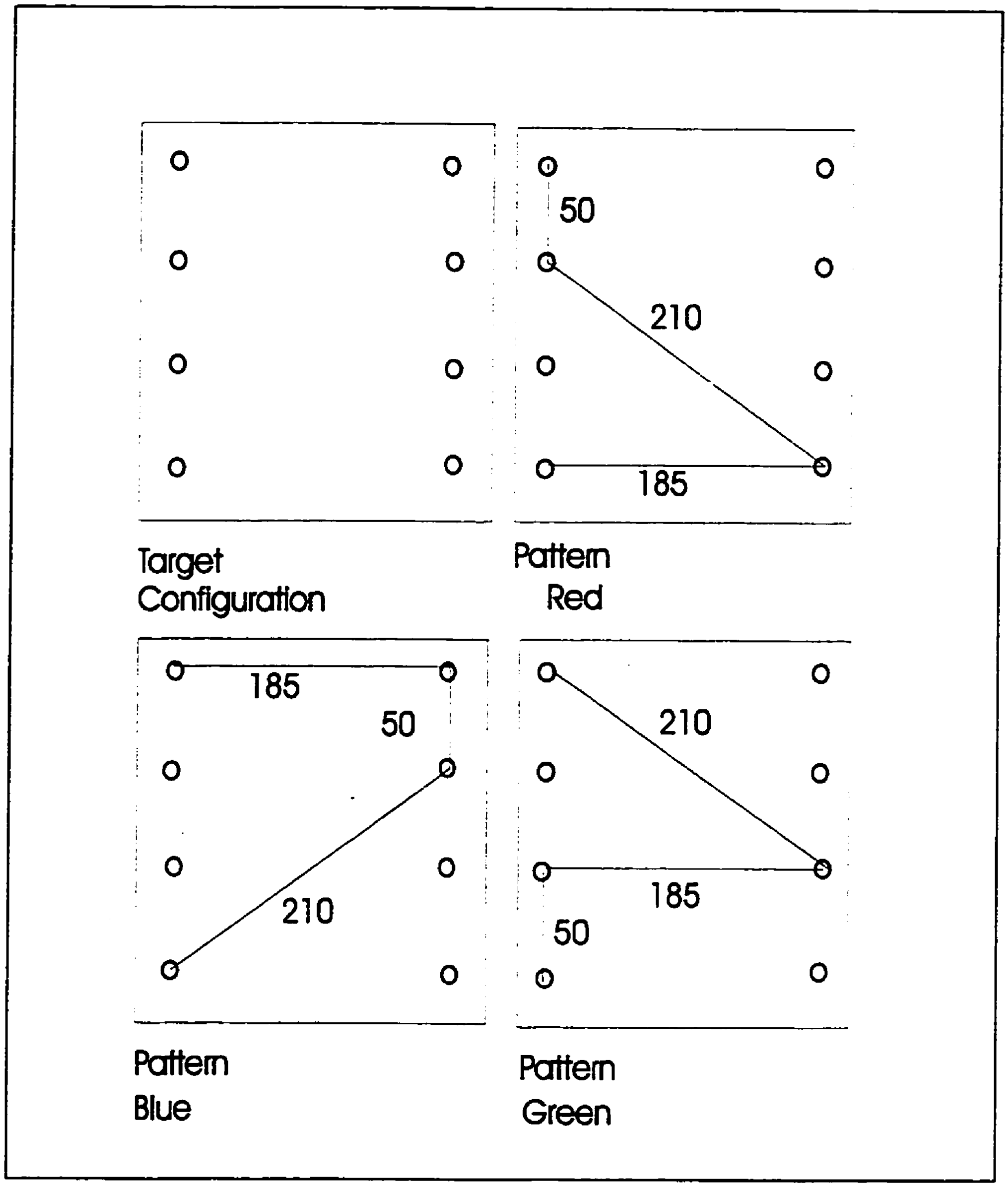

Figure 1. Movement patterns in mm.

During training, the monitor displayed the structure of the pattern in the associated stimulus colour for three seconds before each trial. The removal of the pattern structure from the monitor served as a starting signal to begin movement. The participant then placed the crosshairs of the mouse on the home target situated on the digitising table in preparation for the required movement pattern. The participant was then required to move the mouse as quickly and accurately as possible from the home target to the required targets needed to complete the appropriate three line segment pattern. The computer began recording the accuracy and movement time of the participant's drawing movement as soon as the crosshairs of the mouse left the home target. The computer finished recording the accuracy and movement time of the participant's drawing movement as soon as the crosshairs of the mouse reached the final target of the predetermined pattern.

The computer recorded the pattern error frequency for each pattern. A pattern error was recorded if a participant missed a target, or drew the incorrect pattern. The computer recorded the frequency of both types of pattern error.

Procedure

Acquisition. Participants were randomly assigned to one of four different conditions (n=12). Participants received a description of the task and general procedure for the testing (see Appendix C for participant instruction sheet). The four experimental conditions were distinguished by the different acquisition schedules. The four acquisition conditions were: (a) blocked, (b) random, (c) random-blocked, and (d) blocked-random. Participants in all experimental conditions performed 24 trials of each movement pattern for a total of 72 acquisition trials (see Table 1 for experimental conditions design). The pattern variations for all blocked schedules were counterbalanced as a control to avoid a potential practice order effect. Practice order effects may occur when patterns are always presented in the same order. For example, one participant practised a block of the red pattern, then blue, finishing with the green pattern. The presentation order of the blocked pattern trials then changed for the next participant (i.e., green, red, and blue). The pattern variations in the blocked schedule had equal representation.

Participants in the blocked condition practised all 24 acquisition trials of one movement pattern before switching to the next movement pattern. The random condition practised 24 trials of each of the three movement patterns in a random order, thus preventing the predictability of the next trial. Participants in the random-blocked condition began acquisition with 36 randomised trials (i.e., 12 trials of each movement pattern in random order). Subsequently, the participant practised 36 blocked trials (i.e., 12 trials of each movement pattern). The blocked-random condition began acquisition with 36 blocked trials (i.e., 12 of each pattern) and then followed with 36 random order trials (i.e., 12 of each pattern).

Visual feedback was displayed on the monitor at the end of each trial. The visual feedback consisted of movement time of the pattern (ms), and the accuracy of the pattern. The accuracy of the pattern was reported as either "correct", "missed a target", or "incorrect pattern". The computer noted a mistrial if a participant missed a target, or drew the wrong pattern. At the end of the block of trials the participant repeated the mistrial.

Retention. Following the acquisition trials, there was a ten-minute retention interval. During the retention interval the participants participated in the computer version of the card game Solitaire. After the retention interval, participants completed a 12 trial randomised retention test of the three movement patterns (i.e., four trials of each movement pattern). The same three pattern tasks practised during the acquisition trials were performed during retention trials.

Table 1

Experiment One experimental conditions design.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm	Del
B	12 Red	12 Red	12 Blue	12 Blue	12 Green	12 Green	12 R	12 R
R	12 R	12 R	12 R	12 R	12 R	12 R	12 R	12 R
RB	12 R	12 R	12 R	12 Red	12 Blue	12 Green	12 R	12 R
BR	12 Red	12 Blue	12 Green	12 R	12 R	12 R	12 R	12 R

Note. Blocked trials were counterbalanced for practice order effect.

R = Control randomised (i.e., trial block included four trials of each movement pattern).

During retention, the structure of the red, blue, and green patterns were not displayed on the monitor. Instead of displaying the structure of the pattern, the stimulus colour was displayed on the monitor written in the appropriately coloured text (i.e., the word red was written in red, blue was written in blue, and green was written in green). The written stimulus colour was displayed on the monitor for three seconds before each retention trial. The removal of the written colour stimulus from the monitor served as a starting signal for the participant to begin drawing the appropriate pattern. The computer began recording the accuracy and movement time of the participant's drawing movement when the crosshairs of the mouse left the home target.

After a 24-hour delay, participants returned to the lab to complete a randomised 12 trial retention test (i.e., four trials of each movement pattern). Task performance feedback was not available on the computer monitor during either retention test.

Results

The dependent measures for both acquisition and retention performances were movement time (MT) and percentage of correct trials. The computer recorded the total MT required to complete the three segmental patterns for each participant. Incorrect trials were one of two possibilities being incorrect pattern or missed target. For analysis purposes, the MT scores and percentage of correct trials for each of the three patterns were averaged across 12 trials yielding six acquisition blocks, one immediate retention block, and one delayed retention block. The pattern error type was recorded for each mistrial (i.e., missed target, and incorrect pattern).

Preliminary Analysis

The possibility of a difference existing between the patterns was investigated. A one way analysis of variance (ANOVA) was performed for Pattern on the MT obtained from the acquisition and retention phases. The ANOVA was performed to determine if there were any differences between the patterns that had been equated for distance. There was no significant difference for pattern $F_{(2, 798)} = .89$, $p = .41$. As a result of the insignificant difference among the three different patterns, the pattern colour was collapsed for further analysis.

The design for acquisition consisted of two 4 x 6 (Group by Block) mixed factorial ANOVAs with a repeated measure on the last factor. The first analysis was used to determine if the order of trials, B, R, RB, BR, had an effect on the MT during acquisition. The second analysis was used to determine if the order of trials, B, R, RB, BR, had an effect on the percentage of correctly completed trials.

For retention, two 4 x 2 (Group by Immediate versus Delayed Retention) mixed factorial ANOVAs with repeated measures on the last factor were calculated on the MT and percentage of correct trials. These analyses were used to determine if the order of trials, B, R, RB, BR, during acquisition influenced retention performance. The post hoc comparisons of means were performed on significant ANOVA effects using the Student Neuman-Keuls (SNK), with alpha set at $p < .05$.

Acquisition

MT. There was a main effect for Block $F_{(5, 185)} = 33.17$, $p = .00$. The average MT decreased from Block one (MT = 2025.7 ms) to Block six (MT = 1509.1 ms) across the acquisition session. There was also a significant Group by Block interaction $F_{(15, 185)} = 2.78$, $p = .00$.

The SNK post hoc analyses, with alpha set at $p < .05$, were run to determine the significant differences. SNK results indicated that for the MT of Block one in acquisition, Groups 1-4 (B, R, RB, and BR) were significantly different from each other. Of interest is the slower MT of the B group (MT = 2246.6 ms) in comparison to the R group (MT = 2039.7 ms). Also, the BR group had the fastest MT (1684.1 ms) of the four acquisition conditions. By the end of the acquisition phase, all groups had similar MTs. Mean data for MT is plotted in Figure 2. There was no Group main effect $F_{(3, 37)} = 1.22$, $p = .32$.

Error. There was a main effect for Block $F_{(5,185)} = 2.31$, $p = .04$. The block main effect indicated that the percentage of correct trials increased from Block one (92.9%) to Block six (97.2%) across the acquisition session. The percentages of the correctly completed trials are presented in Table 2. There were no other significant main effects or interactions at the p < .05 level (see Appendix F for complete listing of ANOVA tables).[5]

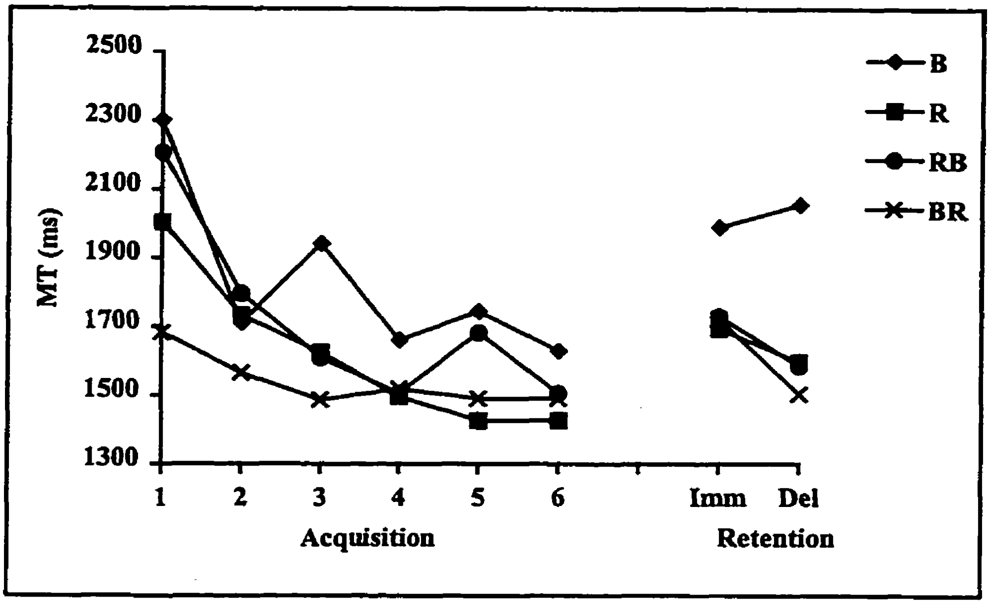

Figure 2. Experiment One MT.

[5] An analysis of variance was performed on the breakdown of the two different types of error. The analysis is presented in Appendix E.

Table 2

Experiment One percentage of trials completed correctly.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
B	94.4 (6.6)	94.1 (9.8)	97.4 (3.9)	98.3 (3.4)	96.7 (5.3)	97.4 (3.9)	64.8 (20.7)	72.2 (23.9)
R	92.1 (6.7)	98.6 (4.5)	97.0 (5.1)	96.6 (7.4)	97.0 (5.1)	94.7 (5.0)	93.3 (12.3)	85.0 (17.9)
RB	96.3 (5.2)	96.3 (5.2)	95.7 (5.1)	96.2 (4.1)	97.8 (4.9)	96.3 (5.2)	78.3 (21.2)	84.2 (23.1)
BR	91.3 (10.3)	95.9 (6.9)	97.1 (6.1)	98.1 (3.5)	95.6 (4.9)	97.4 (3.8)	86.8 (19.9)	87.5 (15.7)

Note. Standard Deviation included in parenthesis.

Immediate and Delayed Retention

MT. There were no significant main effects or interactions at the $p<.05$ level. Mean data for MT is plotted in Figure 2.

Error. There were no significant main effects or interactions at the $p < .05$ level, although the Group main effect was approaching significance $F_{(3, 37)} = 2.47$, $p = .07$. In addition, the Group by Immediate versus Delayed Retention interaction was approaching significance $F_{(3, 37)} = 2.61$, $p = .06$. The results of the error rates are presented in Table 2.

Subsequent Analyses

After analysis of the ANOVA results, further analyses were done to investigate the relationship of the blocked group and random group alone. The results of the RB and BR groups were removed from these analyses. The design for acquisition consisted of two 2 x 6 (Group by Block) mixed factorial ANOVAs with a repeated measure on the last factor. For retention, two 2 x 2 (Group by Immediate versus Delayed Retention) mixed factorial ANOVAs with a repeated measure on the last factor were completed.

Acquisition. For MT there was a main effect for Block $F_{(5, 85)} = 20.02$, $p = .00$. The average MT decreased from Block one (MT = 2152.9 ms) to Block six (MT = 1528.6 ms) across the acquisition session. There were no other significant main effects or interactions at the $p < .05$.

Retention. There was a Group main effect for the MT ($F_{(1,17)} = 5.41$, $p = .03$), and the percentage of correctly completed trials ($F_{(1, 17)} = 6.71$, $p = .02$). The R group had a faster MT (1645.9 ms) in comparison to the B group (MT = 2032.6 ms) and a higher percentage of correctly completed trials (R = 89%, B = 69%). There was also a significant Group by Immediate versus Delayed Retention interaction $F_{(1, 17)} = 4.88$, $p = .04$ for percentage of correctly completed trials.

The SNK post hoc analyses, with alpha set at $p < .05$, were run to determine the significant differences. SNK results indicated that the percentage of correctly completed trials for both Immediate and Delayed Retention of the R group were significantly different from both the Immediate and Delayed Retention scores of the B group.

Discussion

The typical contextual interference effect being increased acquisition performance for a blocked acquisition order in comparison to a random order were not supported for a computer-based pattern drawing task. Similar rates of acquisition were found for random and blocked acquisition conditions. This result is contrary to Battig (1979) and Shea and Morgan (1979) for acquisition but not retention performance.

A possibility for this result could be the notion Lee, Wulf, and Schmidt (1992) suggested about the concept of a "typical" CI effect being incorrect. The generalizability of the CI effect has been a significant issue that has emerged with the surge of motor learning CI research. Two factors may have affected the generalizability of CI in this study. First, the nature of the task may have affected the benefits of CI in acquisition. The absence of acquisition differences between blocked and random practice order has previously been noted for participants learning computer games (Lee & White 1990). It was suggested by Lee and White that CI effects may be greater for tasks that are less intrinsically motivating. The computer-based pattern drawing task may have been interesting and fun to attempt as the participant perceived it as a game to achieve a faster MT. This intrinsic motivation provided by the task, viewed as a computer game, may have accounted for the absence of random/blocked differences in acquisition performance.

Second, participant characteristics such as individual experience or learning styles may have influenced the degree in which the CI effect is affected by acquisition schedule. Participants with prior experience in terms of a specific component that is characteristic of the skill being practised would achieve a higher performance rate during acquisition (Del Rey, 1989; Yoon & Del Rey, 1994). To perform the computer-based pattern drawing task participants had to manoeuvre a four-button mouse on a digitising tablet. Participants previous experience in using a computer mouse may have affected their proficiency and comfort level during acquisition and subsequently provided a possible interaction between CI and the stages of learning a skill.

Cognitive style is another participant related characteristic that has been shown to interact with the contextual interference effect (Jelsma & Pieters, 1989a; 1989b; Jelsma & Van Merrienboer, 1989). These experiments specifically isolated the reflectivity-impulsivity aspect of the participants' learning styles. A reflective person will most often choose an accuracy approach to executing a task, whereas an impulsive person simply responds quickly without taking time to carefully select the right solution. Jelsma and his colleagues hypothesised that reflective participants would have an increased retention performance if their acquisition trials required highly reflective thinking such as that in a high CI acquisition schedule as opposed to a low CI acquisition schedule that requires minimal reflection. In contrast, impulsive participants who practised in a high CI schedule would have a lower retention performance than impulsive participants who practised in a low CI schedule. Jelsma and his colleagues (1989a; 1989b) used computer-based tracing and maze tasks in their investigation of the interaction between reflectivity-impulsivity and the contextual interference effect. The participants used a joystick to move a cursor through the four different mazes that they practised according to either blocked or random schedules. The retention and transfer results supported a significant interaction between cognitive style and acquisition schedule. More specifically, the reflective participants' results supported the CI effect, whereas the results of the impulsive participants did not. Jelsma and Van Merrienboer (1989) account that the effects of CI on retention are related to the degree of reflectivity. Jelsma and Van Merrienboer (1989) investigated the relationship between cognitive style and the CI effect with four novel computerised cursor movement tracking tasks and found similar results to that of Jelsma and Pieters (1989a; 1989b). Therefore, these results indicate that the degree of reflexivity has a positive interaction with the CI effect and must be a consideration when designing particular practice schedules. The question of participant cognitive style was not addressed in the procedure of the current investigation. Thus it is possible that each group had some reflective and impulsive participants and their cognitive style interacted with their acquisition condition.

A final possibility for the lack of CI effect in acquisition could be directly related to the decreased performance of the participants in the blocked group. According to the CI effect, the participants in the blocked group should have a significantly better performance rate in acquisition than participants in the random group. The results indicated that participants had the slowest acquisition MTs in comparison to the random, random-blocked, and blocked-random groups. More notably, the blocked group should have a similar average MT to the blocked-random group for the first three acquisition blocks as they both consisted of blocked trials. The MT for the first three acquisition blocks was considerably slower for the blocked group in comparison to the blocked-random group. It is possible the participants in the blocked group simply did not comprehend the task fully and their slower acquisition MT resulted in the CI effect being insignificant.

In retention, however, the ordinal relationship of the results indicated a trend toward replicating the CI effect, although due to high variability in the results the relationship was not significant. Participants who received random only acquisition trials had a faster MT and greater percentage of completed trials in retention than participants who received blocked only acquisition trials. Results from the subsequent analyses that did not include the two blocked-random combination groups indicate that the typical CI effect was present in retention and significant. By removing two of the experimental groups from the analyses, the total variability in the results was decreased, thus making it easier to find significance to support the CI effect in retention.

The second purpose of this experiment was to establish an increased retention performance of a blocked before random combination acquisition schedule as compared to either a blocked, random, or random before blocked combination acquisition schedule for a computer-based pattern drawing task. Previous studies have shown that practising in a stable, unchanging environment before practising in a changing and unpredictable condition is the determining factor in retention (Goode & Wei 1987). It was found that the acquisition schedule of blocked before random trials was not significantly different from the retention performance of the random only acquisition schedule. Although the BR group did not significantly facilitate the highest retention rate, the blocked before random trials in acquisition did not decrease retention performance in comparison to random only acquisition trials.

Contrasting previous studies, as demonstrated by Shea et al. (as cited in Shea & Zimny, 1983), indicated the amount of random trials in acquisition is the determining factor in retention performance. Shea et al. suggested that the point of CI interpolation may not be a major determinant of subsequent retention, but the amount of random trials may be indicative of retention performance. Groups performing blocked and random acquisition trials in varying orders received only half as much random practice as the actual random condition, and subsequently the random acquisition group would have the highest retention rate. The present study did not support the findings of Shea et al. The practice condition of blocked trials had the lowest retention performance, but the amount of random trials in acquisition did not significantly change retention performance. There were no significant differences in retention between the random, random-blocked, and blocked-random practice conditions. The random group did not perform significantly better than the blocked-random group on delayed retention, therefore, a blocked-random schedule did not seem to result in a detrimental effect on the acquisition of a pattern drawing task.

The issue still remains if blocking trials prior to randomising trials in an acquisition session best facilitates learning. Although not significantly different, the ordinal relationship indicated the BR group had the fastest MT and highest percentage of correctly completed trials in delayed retention. A possible reason for this lack of significance may have been due to the amount of blocked trials before randomising.

Experiment 2

The results from Experiment One indicated that the participants in a blocked before random practice group performed equally in retention as participants in the random only practice group. In addition, the results of Shea, Kohl, and Indermill's (1990) investigation indicated the benefits of blocked practice early in acquisition, whereas the benefits of random practice happen after initial acquisition. The purpose of the second experiment was to further investigate the effect of a blocked before random practice schedule on the acquisition and retention of a pattern drawing task. Different ratios of blocked practice followed by random practice were examined to determine the most effective ratio of blocked-random trials for retention of a computer-based pattern drawing task. The purpose was applied in nature as an effective amount of blocked before random practice trials could be used as a tool for coaches planning practice schedules.

The results of the blocked-random combination practice group from experiment 1 were used for comparison in the statistical analyses of the present experiment. It must be noted that the different ratios of blocked to random trials in the combination conditions offer a relative representation that practitioners may use as a guide. For example, a small amount of blocked to random trials in an acquisition schedule, (e.g., 15 percent), may increase retention performance in comparison to an acquisition schedule with a larger amount of blocked to random trials, (e.g., 50 percent).

Method

Participants

Twenty-four right-handed students from Lakehead University served as participants on a volunteer basis.[6] None of the participants were colour-blind. Participants were naive to the purpose of the study. The participants were different than those who participated in the first experiment.

Apparatus and Task

The same apparatus and task was used as described in experiment one.

Procedure

The experiment consisted of the same three phases as in experiment one: (a) acquisition, (b) immediate retention, and (c) delayed retention.

Acquisition. The procedure for this experiment was identical to the first experiment with the exception that only two conditions were tested. The two experimental conditions were distinguished by the ratio of blocked trials to random trials in an acquisition schedule. Two conditions (n=12), were designated as either blocked-random low (BR-L), or blocked-random medium (BR-M). The results of the blocked-random condition from the first experiment were used within the statistical comparisons of the present experiment. This condition was designated as the blocked-random high

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[6]In retention, two participants, one from the BR-M group, and one from the BR-L group, correctly completed only one trial. There is no variability with one trial result; therefore the data from these participants were removed from the acquisition and retention statistical analyses.

condition (BR-H). The number of blocked trials per condition dictated the low, medium, and high levels that decipher the different experimental conditions (see Table 3 for experimental conditions design). For example, the BR-L condition had the smallest ratio of blocked trials in comparison to random trials (i.e., 1:5), the BR-H condition had the highest ratio of blocked trials in comparison to random trials (i.e., 1:1), and the blocked to random trial ratio for the BR-M condition was between the BR-L and BR-H conditions (i.e., 1:2).

Participants in the BR-L condition began acquisition with 12 blocked trials, (i.e., four trials of each pattern) and then followed with 60 random order trials (i.e., twenty trials of each pattern). The BR-M condition practised 24 blocked trials, (i.e., eight trials of each pattern) immediately followed by 48 randomised trials (i.e., 16 trials of each pattern). The results of the BR-H condition taken from experiment one represented 36 blocked trials, (i.e., 12 trials of each pattern) followed by 36 random order trials (i.e., 12 trials of each pattern). The BR-H condition represented the highest ratio of blocked to random acquisition trials. All blocked trials within the three conditions were counterbalanced for practice order.

Retention. Immediate retention was measured ten minutes following acquisition, whereas delayed retention was 24 hours later. The ten-minute delay interval before the immediate retention test was filled by the participants participating in the computer version of the game Solitaire. Both retention tests consisted of 12 randomised trials (i.e., four trials of each movement pattern). The procedure for the retention tests of this experiment was identical to the first experiment. Feedback was not displayed on the monitor during either of the retention tests.

Table 3

Experiment Two experimental conditions design.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
BR-L	4 Red 4 Blue 4Green	12 R	12 R	12 R	12 R	12 R	12 R	12 R
BR-M	8 Red 4 Blue	4 Blue 8 Green	12 R	12 R	12 R	12 R	12 R	12 R
BR-H	12 Red	12 Blue	12 Green	12 R	12 R	12 R	12 R	12 R

Note. Blocked trials were counterbalanced for practice order effect.

R = Control randomised (i.e., trial block included four trials of each movement pattern).

Results

The dependent measures for both acquisition and retention performances were MT and percentage of correct trials. The computer recorded the total MT required to complete the three segmental patterns for each participant and percentage of trials completed correctly (i.e., no missed targets or wrong patterns). For analysis purposes, the MT scores and percentage of correct trials for each of the three patterns were averaged across 12 trials yielding six acquisition blocks, one immediate retention block, and one delayed retention block.

Preliminary Analysis

The possibility of a difference existing between the patterns was investigated. A one way ANOVA was performed for Pattern on the MT obtained from the acquisition and retention phases. The ANOVA was performed to determine if there were any differences between the patterns that had been equated for distance. There was no significant difference for pattern $F_{(2, 743)} = .45$, $p = .64$. As a result of the insignificant difference among the three different patterns, the pattern colour was collapsed for further analysis.

The design for acquisition consisted of two 3 x 6 (Group by Block) mixed ANOVAs with a repeated measure on the last factor. These analyses were used to determine if the ratio of blocked-random trials, BR-H, BR-M, BR-L, had an effect on the MT or percentage of correct trials during acquisition.

For retention, two 3 x 2 (Group by Immediate versus Delayed Retention) mixed factorial ANOVAs with repeated measures on the last factor were calculated on the MT and percentage of correct trials. These analyses were used to determine if the ratio of blocked-random trials, BR-H, BR-M, BR-L, during acquisition influenced retention performance. The post hoc comparisons of means were performed on significant ANOVA effects using the Student Neuman-Keuls (SNK), with alpha set at $p < .05$.

Acquisition

MT. There was a main effect for Block $F_{(5, 155)} = 16.81$, $p = .00$. The Block main effect indicated that MT decreased from Block one (MT = 1875.3 ms) to Block six (MT = 1433.9 ms) across the acquisition session.

There were no other significant main effects or interactions at the $p < .05$ level. Mean data for MT is plotted in Figure 3. See Appendix F for a complete listing of ANOVA tables.

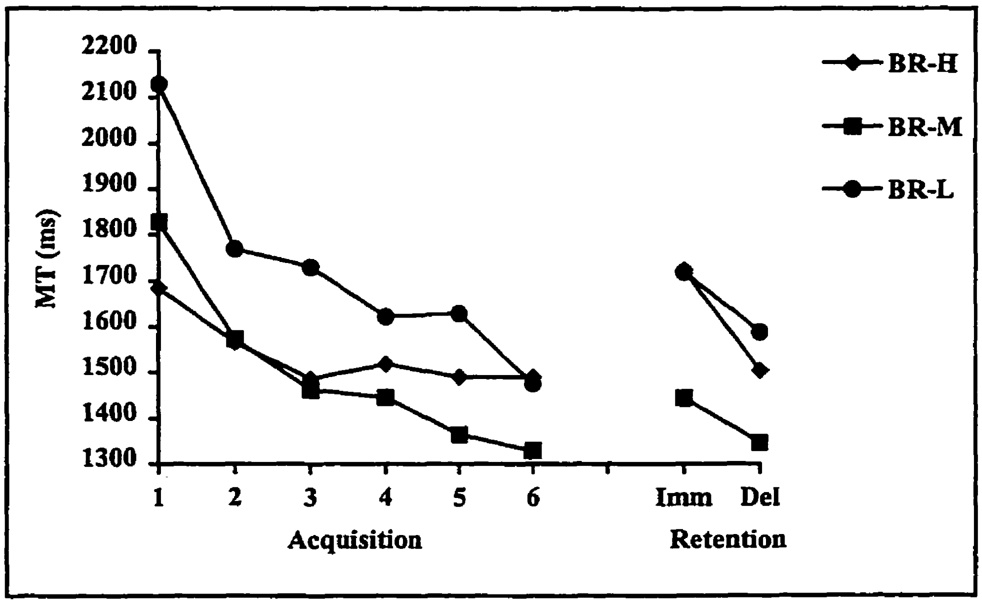

Figure 3. Experiment Two MT.

Error. There were no significant main effects or interactions at the $p < .05$ level, although the Block main effect did approach significance $F_{(5, 155)} = 2.23$, $p = .053$. The results of the error rates are presented in Table 4.

Table 4

Experiment Two percentages of correctly completed trials.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
BR-H	91.3	95.9	97.1	98.1	95.6	97.4	86.8	87.5
	(10.3)	(6.9)	(6.1)	(3.5)	(4.9)	(3.8)	(19.9)	(15.7)
BR-M	96.7	95.2	94.0	95.9	95.5	95.5	95.5	92.4
	(5.9)	(5.0)	(6.3)	(5.1)	(7.1)	(7.1)	(5.7)	(10.2)
BR-L	91.1	98.6	94.8	96.2	96.6	98.6	90.2	87.9
	(8.1)	(3.1)	(6.9)	(7.1)	(5.1)	(3.1)	(16.6)	(17.6)

Note. Standard Deviation included in parenthesis.

Immediate and Delayed Retention

MT. There was a main effect for the retention blocks $F_{(1, 31)} = 4.67$, $p = .04$. The retention main effect indicated that MT decreased from the immediate retention block (MT = 1631.3 ms) to the delayed retention block (MT = 1480.9 ms). Mean data for MT is plotted in Figure 3. No other significant main effects or interactions were indicated.

Error. No significant main effects or interactions were indicated. The results of the error rates are presented in Table 4.

Discussion

The results of Shea et al. (1990) and Goode and Wei's (1988) investigations indicated the benefits of blocked practice early in acquisition, whereas the benefits of random practice happen after initial practice. The purpose of this experiment was to further investigate the notion suggested in the two previous studies that the facilitation of random practice is realised best when blocked practice is used followed by randomising acquisition trials. More specifically the present experiment explored different ratios of blocked before random acquisition trials to determine the most effective ratio of blocked-random trials for retention of a computer-based pattern drawing task.

The three different ratios of blocked before random trials had similar acquisition and retention performances. The BR-L group represented a small amount of blocked before random trials (i.e., 1:5), whereas the BR-M group represented a moderate amount of blocked before random trials (i.e., 1:2), and the BR-H group represented a large amount of blocked before random trials (i.e., 1:1). Although no significance was achieved in the statistical analyses, the BR-M group had both the fastest MT and the highest percentage of correctly completed trials in retention. The BR-L and BR-H groups had almost identical mean MTs and percentage of correctly completed trials. The ordinal relationship would suggest further investigation is warranted to determine if a moderate amount (i.e., 1:2) of blocked before random trials facilitates greater retention as opposed to a low (i.e., 1:5) or high (i.e., 1:1) amount of blocked before random trials. If the ordinal relationship is found to be significant in future investigations (i.e., the BR-M group has the best retention performance), it would imply that there is some amount of blocked trials that could facilitate learning. That is the BR-M group is better than the BR-L group which has too few blocked trials, but there must also be a point when there are too many blocked trials. The question still remains at which point to switch from blocked to random trials to maximise retention performance.

General Discussion

Two contrasting positions have been put forth to indicate the best way to plan an acquisition schedule in order to maximise retention performance. Shea and his colleagues (1981, as cited in Shea & Zimny, 1983) contend that the total number of random trials in comparison to blocked trials determines the level of retention performance. In opposition, other studies (i.e., Goode & Wei, 1987; Shea et al., 1990) have indicated that the benefits of random practice surface after initial practice. Thus random trials are maximised if practised after participants 'get the idea of the movement' (Gentile 1972) through blocked trials.

The results of the first experiment do not support the contention that the amount of random trials directs retention performance. Participants in the BR and RB acquisition groups received half as many random trials as the random only group, but achieved the same level of performance on retention tests. The blocked group did not perform as well in retention as any of the groups with random trials. Therefore, random trials may be necessary in planning an acquisition schedule to optimise retention performance, but the acquisition session need not be totally randomised.

The issue still remains as to when to bring on the random trials in an acquisition session. The ordinal relationship of the results obtained in the second experiment may suggest that blocking trials prior to randomising trials may lead to an increase in retention performance. Although not significantly different, the faster MT and increased percentage of correctly completed trials of the BR-M group in comparison to the BR-H and BR-L groups suggest that further investigation into the blocked/random ratio in acquisition trials is justified.

In varying the ratio of blocked to random trials in an acquisition session, it is difficult to determine the effectiveness of the amount of either random or blocked trials. When the total number of acquisition trials is held constant and the amount of blocked to random trials are varied the effects of the blocked and random trials are covariant upon each other. Future investigations that vary the amount of random trials after a constant amount of blocked trials are performed may give insight to optimizing retention performance. In addition, insight into optimizing retention performance may also be gained by future investigations that vary the amount of blocked trials prior to practising a task in a set amount of random trials.

The lack of significance in Experiments One and Two may be due to the high degree of between participants variability. Participants within the same acquisition condition had a large amount of variability in their performance rates. Mean MT and standard deviations for Experiments One and Two are presented in Appendix D. A possible reason for the high variability rate may lie in the nature of the dependent variables. It is questionable as to what the dependent variable MT is actually representing. A potential problem with MT as a dependent variable is that it may not accurately reflect the acquisition of the learning process that the task was set up to achieve. The task was designed to facilitate learning of a computer-based pattern drawing task. The balance between simply learning the patterns and learning to perform the patterns quickly may be upset when MT is used as a measuring tool.

According to Jelsma and his colleagues, (Jelsma & Pieters, 1989a; 1989b; Jelsma & Van Merrienboer, 1989), there is a reflectivity-impulsivity aspect to a participants' learning style. A reflective person will choose an accuracy approach over fast execution, and an impulsive person will respond quickly as possible without much concern that the task be completed correctly. Having MT as the measuring tool in a pattern drawing task that has both reflective and impulsive participants in the same group could have possibly led to increased variability in the results and thus decreased the likelihood of statistical significance.

It should be noted that MT, more specifically MT combined with reaction time (RT) to make total time (TT), has been commonly used to measure performance in CI investigations. For example, Shea and Morgan (1979) used TT as their dependent measure in the first ever reported study on CI in the motor domain. The results from the study by Shea and Morgan successfully indicated the CI effect. Thus time has been successful as a dependent measure in past studies, but caution should be used as a speed-accuracy trade-off is possible and may increase variability in the results.

The second dependent variable in Experiment One and Two was percentage of correctly completed trials. In order to effectively account for acquisition of a computer-based pattern drawing task this dependent variable should be a more refined accuracy measure of the pattern drawn. This percentage of correct trials attempts to measure accuracy of the drawn pattern. The fault in this calculated percentage is that everything except wrong patterns, and missed targets was considered correct. Therefore, the percentage was only partially indicating the accuracy of the completed task.

Every movement, according to Bernstein (1967), is done in a space-time coordinative structure. Thus all movements have a spatial and temporal parameter associated with it. In the current investigation, an attempt was made to measure the spatial parameter with percentage of correctly completed trials. The inadequacy of this percentage in calculating a true account of pattern accuracy leaves the MT as a critical dependent variable. The MT measures the temporal component of the movements. A potential problem with using MT, as the only measure of performance is it does not take into account how the spatial and temporal parameters work together.

Future tasks should be designed with two changes. First, instead of a 'fast as possible' movement, the pattern could be drawn within a certain time allotment. In other words, the participants would be required to move quickly (i.e., within the reasonably set allotted time), but not with the mindset of finishing the task as quickly as possible. Being required to finish the task within the reasonable time allotment may help to neutralise the impulsive participants' tendency to trade off accuracy for a faster speed. Thus, the use of

MT as a dependent variable should be carefully contemplated in future investigations on contextual interference of computer-based pattern drawing tasks.

The second suggestion for future investigations is to change the second dependent variable being percentage of correctly completed trials to measuring the total amount of error during task execution. By calculating the total amount of error (e.g., by how many mm was the target missed), the dependent variable will more accurately represent the accuracy of the task completed. Thus, by controlling the speed used by the participants and being more exact on the measurement of task accuracy, the experimental environment would be more controlled and any potential speed-accuracy trade-offs would be avoided. This avoidance of a possible speed-accuracy trade-off interaction with the contextual environment may decrease future levels of variability in the results. With the decreased amount of variability in the results the study would better isolate and indicate performance regarding practice condition.

Summary

The results of the present investigation have implications for practitioners planning acquisition sessions. According to the theoretical viewpoint of CI, practitioners should plan acquisition schedules with high CI (i.e., random trials) at all times in order for a high retention return rate. The current study found that a blocked before random combination acquisition schedule did not decrease the benefits of high retention performance. Practice conditions beginning with blocked trials before random trials may allow the learner to get the idea of a movement before they have to perform it in a changing environment. Thus practitioners should consider planning practice sessions with progressively increasing levels of contextual interference to attain the highest retention performance possible. The amount of low contextual interference (i.e., blocked trials) that should be scheduled before introducing a highly contextual environment (i.e., randomised trials) is still unclear. The question still remains as to when to switch the practice schedule from blocked to random trials.

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Appendix A

Task Similarity Predictions

The elaboration viewpoint endorses similar predictions to those put forth by Battig (1972, 1979). The forgetting and reconstruction hypothesis predicts that increased task similarity causes a decrease in CI. Increased task similarity causes a decrease in the variability of the practised tasks. The action plans are not forgotten from working memory, as the task similarity is high. Thus, reconstruction of the action plans is not necessary, as only certain parameters need to be re-scaled.

According to the elaboration viewpoint, increased levels of CI result when practising highly similar tasks. Distinguishing the tasks from each other requires multiple encoding strategies. O'Donnell (1993, exp. 1) supported the notion that increased skill similarity positively affected CI. In contrast, deeper processing is not required for highly dissimilar tasks. Highly dissimilar tasks are easily distinguished and would not require multiple encoding strategies. O'Donnell (1993, exp. 2) investigated the relationship between task similarity and scheduling presentation. O'Donnell's results demonstrated that the combined group of similar patterns presented in a random sequence generated the greatest amount of CI, thus indicating an interactive effect.

Appendix B

CONSENT FORM

My signature on this form indicates that I agree to participate as a participant in a research project in the Motor Learning Laboratory at Lakehead University, on Practice Schedule Variations. I understand that my participation in this study is conditional on the following:

1. I have read the cover letter and have had the experiment explained to me.

2. I fully understand what I will be required to do as a participant in the study.

3. I am a volunteer participant and may withdraw from the study at any time. If I am a Lakehead student my withdrawal from the study will not result in academic penalty.

4. There are no known physical or psychological risks associated with participation in this study.

5. My data will be confidential.

6. I will receive a summary of the project, upon request, following the completion of the project.

________________________ __________
Signature of Participant Date

________________________ __________
Signature of Witness Date

Appendix C

INSTRUCTIONS

The task to be performed is a pattern learning task utilising a mouse and a digitising tablet. Each pattern consists of three line segments and is paired with a different colour stimulus. Stimulus colours are red, blue, and green.

An eight target configuration is mounted on the digitising tablet and is directly proportional to the eight targets that will remain on the monitor. The lower left target serves as the home target from which all movement patterns begin.

During the acquisition trials, the monitor will display the structure of the pattern in the associated stimulus colour for three seconds before each trial. The removal of the pattern structure from the monitor serves as a starting signal from which movement may begin. To perform the movement, first place the crosshairs of the mouse on the home target situated on the digitising tablet. When you are ready move the mouse as quickly and accurately as possible from the home target to the required targets needed to complete the appropriate three line segment pattern. Once you have reached the final target of the predetermined pattern, the trial has been completed. After completing the trial, return the mouse to the home target in preparation for the next trial. The computer will then prompt you to hit the space bar in order to retrieve feedback on the performance of the trial.

Visual feedback will be displayed on the monitor at the end of each trial in the form of movement time (ms) and accuracy of the pattern. The accuracy of the pattern is reported as either "correct", "missed a target", or "incorrect pattern". All trials that are not "correct" will be repeated at the end of the block of trials.

The acquisition phase will consist of six (6) blocks of twelve (12) trials. The time between trials is self-paced.

Following the acquisition phase, there will be two retention tests. The first retention test will occur after a ten-minute delay and the second will occur after a 24-hour delay. Each retention test will consist of one (1) block of twelve (12) trials. During retention, the structure of the red, blue, and green patterns will not be displayed on the monitor. The stimulus colour written in the corresponding colour will be displayed on the monitor to inform you of which pattern to draw. Task performance feedback will not be available on the computer monitor during either retention test.

Please note that it is important that the trials are performed as quickly and as accurately as possible. If you have any questions please ask the experimenter now, before any testing begins.

Appendix D

Table D1

Experiment One Mean MT in ms.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
B	2300.7	1712.0	1942.2	1660.2	1743.8	1629.2	1990.1	2055.1
	(774.9)	(552.4)	(293.9)	(318.1)	(366.8)	(392.8)	(341.1)	(558.2)
R	2005.1	1735.6	1625.8	1496.1	1427.5	1428.1	1694.8	1597.0
	(439.8)	(343.7)	(308.2)	(291.4)	(320.5)	(288.5)	(308.1)	(280.8)
RB	2208.7	1797.6	1611.1	1505.5	1683.4	1505.3	1729.2	1586.7
	(725.5)	(542.0)	(468.9)	(454.0)	(458.3)	(335.2)	(548.0)	(447.3)
BR	1684.1	1566.5	1485.9	1517.7	1490.3	1489.6	1722.7	1504.4
	(366.6)	(293.7)	(256.7)	(335.3)	(361.3)	(349.1)	(601.1)	(372.1)

Note. Standard Deviation included in parenthesis.

Table D2

Experiment Two Mean MT in ms.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
BR-H	1684.1 (366.6)	1566.5 (293.7)	1485.9 (256.7)	1517.7 (335.3)	1490.3 (361.3)	1489.6 (349.1)	1722.7 (601.1)	1504.4 (372.1)
BR-M	1829.3 (497.7)	1573.3 (345.0)	1462.9 (322.1)	1445.6 (365.1)	1365.4 (418.3)	1329.8 (408.2)	1443.5 (397.3)	1346.4 (341.4)
BR-L	2130.0 (847.9)	1769.7 (532.9)	1731.2 (493.8)	1622.8 (493.7)	1630.1 (425.3)	1477.1 (300.4)	1719.4 (390.4)	1589.7 (449.9)

Note. Standard Deviation included in parenthesis.

Appendix E

Error Type

There were two different types of error recorded in this investigation. An error consisted of either a missed target or wrong pattern. In an attempt to gain insight into the participant's cognitive style error patterns may be utilised. More specifically, the participant's tendencies to be either reflective or impulsive were investigated by breaking down the type of errors made (missed targets versus wrong patterns). Wrong patterns are more indicative of learning errors whereas missed targets may give some insight into the reflectivity-impulsivity nature of the participants. If a participant had a high amount of 'missed targets' it may be because the participant was being impulsive as they moved too quickly.

The design for Experiment One acquisition consisted of a 4 x 2 x 6 (Group by Error by Block) mixed factorial ANOVA with a repeated measure on the last factor. The analysis was used to determine if the order of trials, B, R, RB, RB, had an effect on the type of error encountered during acquisition. For retention, a 4 x 2 x 2 (Group by Error by Immediate versus Delayed Retention) mixed factorial ANOVA with a repeated measure on the last factor. This analysis was used to determine if the order of trials, B, R, RB, BR, during acquisition influenced the type of error encountered during the retention trials.

In Experiment Two, a 3 x 2 x 6 (Group by Error by Block) mixed factorial ANOVA with repeated measures on the last factor was used for the acquisition analysis.

The analysis was used to determine if the order of trials, B, R, RB, RB, had an effect on the type of error encountered during acquisition. For retention, a 3 x 2 x 2 (Group by Error by Immediate versus Delayed Retention) mixed factorial ANOVA with a repeated measure on the last factor. This analysis was used to determine if the order of trials, B, R, RB, BR, during acquisition influenced the type of error encountered during the retention trials.

There were no significant differences between the amount of missed targets versus wrong patterns, although the error type did approach significance in the acquisition of both experiments. The mean percentages for each of the error types are presented in Tables E1-E4. In addition, for a complete listing of ANOVA tables see Appendix F.

Further research into the nature of the participant's reflectivity/impulsivity is warranted. For example, a questionnaire could be developed to determine a participant's cognitive style so that reflectivity-impulsivity may be isolated and controlled within further CI analyses.

Table E1

Experiment One Mean Percentage of Missed Targets.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
B	3.97	5.86	1.71	0.86	0.79	0.86	18.52	9.24
	(5.03)	(9.85)	(3.40)	(2.57)	(2.37)	(2.57)	(14.89)	(14.08)
R	5.74	0.71	2.97	3.43	2.97	3.74	0.00	4.16
	(7.09)	(2.25)	(5.11)	(7.35)	(5.11)	(5.19)	(0.00)	(10.57)
RB	2.25	2.20	3.74	3.08	1.48	2.25	4.16	5.83
	(3.63)	(4.89)	(5.19)	(3.98)	(3.12)	(3.63)	(8.09)	(12.45)
BR	6.08	4.14	2.31	0.64	3.21	1.93	0.69	1.38
	(7.52)	(6.86)	(5.99)	(2.22)	(3.96)	(3.48)	(2.40)	(3.23)

Note. Standard Deviation included in parenthesis.

Table E2

Experiment One Mean Percentage of Wrong Patterns.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
B	1.60	0.00	0.86	0.86	2.50	1.71	16.66	18.51
	(3.18)	(0.00)	(2.57)	(2.57)	(3.75)	(3.40)	(15.01)	(25.25)
R	2.20	0.71	0.00	0.00	0.00	1.54	6.66	10.83
	(4.89)	(2.25)	(0.00)	(0.00)	(0.00)	(3.25)	(12.29)	(17.59)
RB	1.48	1.54	0.77	0.77	0.71	1.48	17.50	9.99
	(3.12)	(3.25)	(2.43)	(2.43)	(2.25)	(3.12)	(15.44)	(16.09)
BR	2.68	0.00	0.64	1.28	1.19	0.64	12.50	11.10
	(4.99)	(0.00)	(2.22)	(2.99)	(4.13)	(2.22)	(18.64)	(16.40)

Note. Standard Deviation included in parenthesis.

Table E3

Experiment Two Mean Percentage of Missed Targets.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
BR-H	6.08	4.14	2.31	0.64	3.21	1.93	0.69	1.38
	(7.52)	(6.86)	(5.99)	(2.22)	(3.96)	(3.48)	(2.40)	(3.23)
BR-M	0.65	2.75	3.95	4.10	3.25	3.86	3.72	6.75
	(2.14)	(3.81)	(5.89)	(5.07)	(4.79)	(6.36)	(4.28)	(9.71)
BR-L	3.79	0.70	3.22	2.61	3.40	0.00	7.57	6.81
	(6.33)	(2.32)	(6.36)	(4.84)	(5.05)	(0.00)	(15.12)	(13.33)

Note. Standard Deviation included in parenthesis.

Table E4

Experiment Two Mean Percentage of Wrong Patterns.

	Acquisition						Retention	
	1	2	3	4	5	6	Imm.	Del.
BR-H	2.68	0.00	0.64	1.28	1.19	0.64	12.50	11.10
	(4.99)	(0.00)	(2.22)	(2.99)	(4.13)	(2.22)	(18.64)	(16.40)
BR-M	2.65	2.05	2.05	0.00	1.25	0.65	0.75	0.75
	(4.87)	(3.51)	(3.51)	(0.00)	(2.79)	(2.14)	(2.50)	(2.50)
BR-L	5.11	0.70	2.00	1.21	0.00	1.40	2.26	5.30
	(6.70)	(2.32)	(4.69)	(4.01)	(0.00)	(3.11)	(3.88)	(12.52)

Note. Standard Deviation included in parenthesis.

Appendix F

Table Fl

Experiment One: ANOVA Results for MT in Acquisition.

Effect	df Effect	df Error	MS Error	F	p-level
Group	3	37	803642.4	1.21633	.317380
Block	5*	185*	47021.5*	33.16540*	.000000*
Interaction	15*	185*	47021.5*	2.78948*	.000638*

Table F2

Experiment One: ANOVA Results for Correctly Completed Trials in Acquisition.

Effect	df Effect	df Error	MS Error	F	p-level
Group	3	37	39.52937	.107960	.954916
Block	5*	185*	32.40138*	2.313299*	.045577*
Interaction	15	185	32.40138	.783553	.694821

Table F3

Experiment One: ANOVA Results for Error Type in Acquisition.

Effect	df Effect	df Error	MS Error	F	p-level
Group	3	37	19.77735	.112286	.952375
Error	1	37	16.32040	3.410813	.072780
Block	5*	185*	17.21385*	4.753497*	.000413*
Group/Error Interaction	3	37	16.32040	.511766	.676666
Group/Block Interaction	15	185	17.21385	.719075	.763344
Error/Block Interaction	5	185	16.52245	1.841922	.106692
Group/Error/ Block Interaction	15	185	16.52245	1.113161	.347107

Table F4

Experiment One: ANOVA Results for MT in Retention.

Effect	df Effect	df Error	MS Error	F	p-level
Group	3	37	803646.2	2.079458	.119607
Imm. vs. Del.	1	37	67436.8	2.912918	.096254
Interaction	3	37	67436.8	1.058043	.378598

Table F5

Experiment One: ANOVA Results of Correctly Completed Trials in Retention.

Effect	df Effect	df Error	MS Error	F	p-level
Group	3	37	667.8889	2.468545	.077196
Imm. vs. Del.	1	37	93.7435	.427002	.517504
Interaction	3	37	93.7435	2.618235	.065307

Table F6

Experiment One: ANOVA Results of Error Type in Retention.

Effect	df Effect	df Error	MS Error	F	p-level
Group	3	37	333.7087	2.468845	.077170
Error	1	37	46.8426	.430484	.515812
Imm vs. Del	1*	37*	324.9221*	6.965038*	.012093*
Group/Error Interaction	3	37	46.8426	2.623705	.064910
Group/Imm vs. Del Interaction	3	37	324.9221	.285468	.835565
Error/Imm vs. Del Interaction	1	37	73.6325	.000142	.990564
Group/Error/Imm vs Del Interaction	3	37	73.6325	2.268093	.096682

Table F7

Experiment Two: ANOVA Results of MT in Acquisition.

Effect	df Effect	df Error	MS Error	F	p-level
Group	2	31	830739.4	1.17008	.323674
Block	5*	155*	50661.1*	16.81114*	.000000*
Interaction	10	155	50661.1	1.49872	.144554

Table F8

Experiment Two: ANOVA Results of Correctly Completed Trials in Acquisition.

Effect	df Effect	df Error	MS Error	F	p-level
Group	2	31	830739.4	1.17008	.323674
Block	5*	155*	50661.1*	16.81114*	.000000*
Interaction	110	155	50661.1	1.49872	.144554

Table F9

Experiment Two: ANOVA Results of Error Type in Acquisition.

Effect	df Effect	df Error	MS Error	F	p-level
Group	2	31	27.03882	.089434	.914684
Error	1	31	17.35854	3.968273	.055236
Block	5*	155*	17.04751*	3.109428*	.010545*
Group/Error Interaction	2	31	17.35854	.636962	.535678
Group/Block Interaction	10	155	17.04751	1.028211	.422321
Error/Block Interaction	5	155	18.77349	1.191160	.316032
Group/Error/ Block Interaction	10	155	18.77349	1.674441	.091242

Table F10

Experiment Two: ANOVA Results of MT in Retention.

Effect	df Effect	df Error	MS Error	F	p-level
Group	2	31	300270.8	1.437988	.252803
Imm. vs. Del.	1*	31*	80061.9*	4.666305*	.038607*
Interaction	2	31	80061.9	.284701	.754185

Table F11

Experiment Two: ANOVA Results of Correctly Completed Trials in Retention.

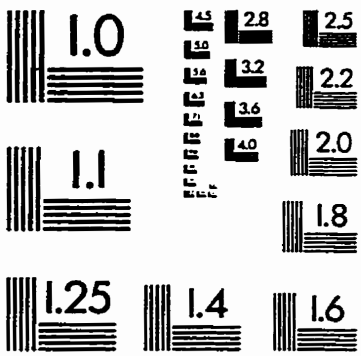
Effect	df Effect	df Error	MS Error	F	p-level
Group	2	31	300270.8	1.437988	.252803
Imm. vs. Del.	1*	31*	80061.9*	4.666305*	.038607*
Interaction	2	31	80061.9	.284701	.754185

Table F12

Experiment Two: ANOVA Results of Error Type in Retention.

Effect	df Effect	Df Error	MS Error	F	p-level
Group	2	31	203.6386	.697845	.505305
Error	1	31	26.6733	.745263	.394610
Imm vs. Del	1	31	197.6659	.157831	.693883
Group/Error Interaction	2	31	26.6733	425073	.657475
Group/Imm vs. Del Interaction	2*	31*	197.6659*	4.263377*	.023136*
Error/Imm vs. Del Interaction	1	31	23.2267	.070617	.792200
Group/Error/Imm vs Del Interaction	2	31	23.2267	1.636286	.211073

IMAGE EVALUATION TEST TARGET (QA-3)



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