The Effect of Random, Blocked, and Transition Practice Schedules on Children's Performance of a Barrier Knockdown Test

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Abstract

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The purpose of this research was to examine whether a transition schedule of contextual interference facilitated learning in retention and transfer equal to or better than random and blocked schedules among children. The author selected participants from the central coast of California and from youth activity leagues. The author selected children between the ages of 10 to 13 with a mean age of 11.5. There were a total of 36 subjects, half male and half female. Unfortunately, due to computer error, only data from 15 subjects were saved and available for analysis. Researchers randomly assigned participants to one of three groups: the random group, the blocked group, or the transition group. Each group performed 60 trials during the acquisition phase and practiced a total of 3 different arm patterns. All three groups practiced each pattern a total of 20 times during acquisition. The random group practiced each pattern in random fashion such that no one pattern was repeated more than twice in a row. The blocked group performed 20 trials of the green pattern, followed by 20 trials of the blue pattern, and lastly 20 trials of the red pattern. The transition group performed the first 24 trials in a blocked fashion, that is 8 trials of the green pattern were practiced, followed by 8 trials of the blue pattern, and then 8 trials of the red pattern. The group then practiced smaller blocks and performed 5 trials of each color. Another 9 trials were performed in a blocked fashion with 3 trials of each pattern. The final 12 trials were presented randomly to this group.

Following acquisition, participants took an immediate retention test that was counter balanced following a 10 minute rest. The retention test consisted of 9 random trials of the three various patterns. Researchers gave a transfer test following the retention test, which consisted of six trials of a novel (white) pattern. Researchers tested all three groups one week later with a delayed retention and transfer test similar to the tests described above. One-way ANOVA analysis of the data revealed a significant movement time difference ($F=4.28$; $P=.039$) during the delayed retention test. The follow up Tukey test demonstrated that the transition group had a significantly faster movement time than the blocked group but that random group was not significantly different from either the blocked or transition group. The other retention and transfer tests revealed no significance, however the trend in the data suggest that with a bigger sample size, the transition group would demonstrate learning equal to or better than both random and blocked groups. Further research is needed in the area of transition practice schedules.

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Chapter 1

Introduction

Background of Problem

Researchers have shown that the contextual interference effect can be a robust factor that influences learning (for a review, see Magill & Hall, 1990). However, the research on practice schedules when it comes to teaching children is inconclusive and lacking. During learning situations, whether in school or on a practice field, children usually practice the same skill over and over again until the teacher or coach feels that the child has learned that skill. While this seems logical to a grade school teacher or the average parent that happens to volunteer to coach their child's little league team, it may not be the most effective way to teach a child. If researchers found that children are able to respond to high degrees of contextual interference like adults, then the typical practice schedule that most children undergo in school and on city recreational teams during after school practices is not promoting the best kind of learning environments for our children.

When practicing skills, a high contextual interference condition would be when the tasks for the practice are presented in a randomized schedule, e.g., A, C, B, B, A, B, C, A, C…., while a low contextual interference condition would be when each task is blocked, e.g., AAA…BBB…CCC… For example, a blocked practice schedule for a volleyball player would be to continuously practice one skill (the set) over and over until learned before moving on to a new skill (the spike), while a randomized practice schedule would consist of the athletes switching between the set and spike and practicing both skills simultaneously.

When considering open skills, it makes sense that learning several different tasks that help an athlete cope with an ever changing environment would lead to a greater learning of those skills. However, this idea of contextual interference when learning a closed skilled is not nearly as obvious as when practicing an open skill. The logical assumption would be that because the closed skill always remains the same (e.g. bowling, darts), an athlete need only to practice that skill over and over to learn it. However logical this may be, researchers have suggested to the contrary that a randomized practice schedule may also be important in closed tasks as well (Shea & Kohl, 1991).

Assuming that practicing several skills at one time is beneficial, the order in which a coach schedules the practice can also play a role in motor skill learning. Shea and Morgan (1979) introduced practice scheduling to the motor skill domain but it originated with the work of William Battig. Battig (1956, 1979, & 1972) suggested that variables that made tasks more difficult during acquisition usually degraded performance during practice but generally improved or enhanced learning as demonstrated using transfer or retention tests. Ultimately, Battig found that learning was enhanced more for subjects that underwent a randomized practice schedule when compared to repetitious blocks of practice. Battig defined this phenomenon as “contextual interference” because there was a disruption or interference which caused a context free environment for the skills to be learned. Shea and Morgan (1979) tested Battig’s theory of contextual interference in the motor learning field. They examined whether a blocked (practicing one skill until learned) or random (practicing several skills at the same time) practice schedule would lead to greater learning of a motor task. Subjects in the Shea and Morgan study responded to 3 different light stimuli with a rapid arm movement and depending on the stimulus produced one of three movement patterns. The subjects held a tennis ball in their hand and knocked over the barriers with various patterns in a 4 segment arm movement.

The subjects were tested on their reaction time to initiate the arm movement and their overall movement time to produce the pattern. There were 54 total trials in acquisition with each of three different arm patterns being practiced 18 times. The blocked group would practice the same pattern 18 times in a row before moving on to the next pattern while the random group performed all 3 different arm patterns in a random order. If Battig and his contextual interference learning theory were correct, then the randomized practice schedule would decrease performance during acquisition but enhance overall learning demonstrated by a retention test. Indeed, Shea and Morgan found that the contextual interference effect did exist for a randomized practice schedule during their barrier knock down task because the random group performed significantly better on both a 10 minute and 10 day retention test. Also, the random group performed significantly better on both the random and blocked test.

Initially, it would seem difficult to understand how a variable that seems to suppress performance during acquisition could also significantly enhance performance during retention. However, two major hypotheses have been proposed to explain why the contextual interference effect is so effective in a motor learning setting. The first hypothesis, known as the elaborative processing hypothesis, was proposed by Battig and relies heavily on inter-task processing. Proponents of this theory suggest that the differences in task requirements during randomization cause the learner to make a comparative and contrastive analysis between each task. These cognitive processes cause learners to clearly make a distinction between each task and also each task becomes individually more memorable. During blocked practice, the opportunity for making a comparison between tasks is reduced due to the repetitive nature of the practice schedule. When subjects practice tasks simultaneously and hold them in short term memory together, the learner undergoes a more comparative process. An example of the elaborative processing hypothesis could be seen if one had to compare and contrast the two different works of art. It is more effective to compare and contrast two paintings hanging side by side on the wall as opposed to in two separate rooms. If the paintings were in two separate rooms, the subject would have less comparative opportunities available at a given moment. This process would definitely fall short and the subject would definitely not be as successful in making comparisons as had the paintings been side by side.

Lee and Magill (1983) proposed another explanation for why contextual interference is effective and called it the reconstruction hypothesis. According to Lee and Magill, learning is enhanced when the subject is forced to reconstruct their movement pattern when they are given a random presentation of trials. If the subject is allowed to remember what they just performed, as is the case with blocked practice, immediate performance will improve but sustained learning of that task will be reduced. This hypothesis is best explained by trying to understand the “forgetting helps remembering” paradox introduced by Cuddy and Jacoby (1982). For example, consider a child learning arithmetic. If they are practicing multiplying two numbers together and the same problem is repeated over and over, then the mental arithmetic needed to solve the problem is not needed because the answer still resides in their short term working memory. However, if the child forgets the solution, then they must undergo the full process of solving the multiplication problem over again, thus enhancing learning. Researchers in the motor learning domain have tested this same deeper learning effect.

Since Shea and Morgan's (1979) landmark study, there have been scores of other researchers that have also found the contextual interference effect to be present during laboratory settings (Lee & Magill, 1983, Magill & Hall, 1990). Similarly, when researchers compared random with a blocked practice schedule in the applied setting it too has demonstrated to enhance learning. Porter, Landin, Hebert, and Baum, (2007) found that when practiced together in a random schedule, subjects learn the golf chip and putt more effectively as opposed to practicing them separately. However, in a meta-analysis Frank (2007) concluded that the CI effect is far more prevalent in laboratory settings than in the field which tend to find inconclusive results. Frank also found that while contextual interference research concerning adults is abundant, it is rather lacking among children.

Children

In 1999, Jarus and Goverover investigated the CI effect among children and found that there was no significance difference among the subjects under any of the various practice schedules and suggested that the randomization may not enhance learning for children. The authors concluded that young children might need to practice the same skill over and over again to establish a movement schema before they can move onto another task. This was consistent with Magill and Hall (1990) who suggested that perhaps the difficulty of high CI practices might overwhelm learners in the early stages of acquisition. It is possible that children and novices need some degree of proficiency before benefits of high CI are realized. However, in a more recent study, Vera and Montilla (2003) found that a randomized practice schedule did significantly enhance learning for young children and argued against notions that children are easily overwhelmed by high CI.

Moderate CI

In addition to blocked and random practice schedules, research has also been conducted on a type of randomized-blocked schedule knows as moderate CI. With a typical moderate schedule, a subject practices 2 or 3 trials of the same task and then is randomly switched to another task for 2 or 3 trials. However, there can be slight variations on a moderate schedule that affect acquisition and learning. A type of variation is a transitional schedule where subjects start off practicing under blocked schedules but are "transitioned" throughout acquisition into a more randomized schedule until they are practicing under a fully randomized schedule in their final trials.

Pigott & Shapiro (1984) and Al-Ameer and Toole (1993) supported this "middle of the round" type contextual interference because they argued that performance during acquisition wasn't nearly as degraded as it was during randomization and the moderate schedule was just as beneficial to learning as was the randomized schedule. Landin and Herbert (1997) would later confirm these conclusions in an applied setting with a study on basketball shooting where the group that performed under a moderate CI schedule actually performed best during both the acquisition stage as well as during retention. The researchers argued that moderate levels of contextual interference may be superior because it combines the best features of both high CI and low CI. Moderate CI allows the learner to make adjustments on the task because of the 3 trials in a row but also still offers the benefits of high CI by requiring each subject to perform several different tasks per practice session.

Problem and Purpose Statements

It is unclear whether a transitional schedule is best during retention and transfer for children learning a new motor skill. Therefore, the purpose of this research was to examine whether a transition schedule would facilitate learning in retention and transfer equal to or better than random and blocked schedules among children performing a barrier knockdown task.

Research Hypothesis

Previous contextual interference research concerning children (Vera and Montilla, 2003) and moderate CI practice schedules (Landin & Herbert, 1997; Pigott & Shapiro, 1984; Al-Ameer and Toole, 1993), suggests that the children who perform the moderate level of contextual interference practice will demonstrate enhanced learning when compared with the group who performs random and repetitious blocks of practice. Therefore, a transitional CI schedule that begins each subject with a blocked schedule but slowly moves them to a randomized format could incorporate the benefits of moderate CI and thus facilitate learning to the highest degree.

Justification

Although recently there has been more research concerning the CI effect among children subjects, there is still a debate as to whether the CI effect enhances learning. Jarus and Goverover (1999) found that the CI effect did not exist among children when learning a simple throw of a bean bag onto a target, however Vera and Montilla (2003) found that their random group performed better on both the retention and transfer tests of a similar tossing skill, confirming the CI effect. Zetou, Michalopoulou, Giazitzi, and Kioumourtzoglou (2007) examined the difference between a low and high contextual interference effect on learning volleyball skills in 26 novice female players with an average age of 12.4 years and concluded that either a blocked or random practice schedule could be effective for teaching volleyball to unskilled children. Laura and French (2007) conducted a similar study of 9th graders learning the bump, set, and spike in random, blocked, or random-blocked practice schedules. Like Zetou et al. (2007), they too found no significant difference in motor behavior learning among the various practice schedules. However, Ste-Marie et al. (2004) found that effects of high contextual interference on handwriting skill among elementary school students to be significantly beneficial when compared to repetitious blocks of practicing the same letter over and over. There still remains several questions as to the effectiveness of contextual interference among children and we look to answer some of those questions with our study.

Another need for this study comes from the lack of research done on other types of practice schedules. Lee and Wishart (2005) wrote that although many variables influence learning, none is more important than the amount of practice. Ultimately, the more practice one receives, the more improvement gained. Lee and Wishart argue that although high levels of CI may increase learning, it will usually always degrade performance initially and this can discourage athletes and ultimately cause them to terminate practicing that skill. If no factor is more important than just the amount of practice, then trying to incorporate a practice schedule that could discourage future practice, no matter how successful in retention, may prove to be detrimental. Bjork

(1998) said, "Doing anything during training that increases errors or decreases the rate of improvement will not, therefore, tend to be well received—not by management, not by instructors, and not by trainees themselves" (p. 454). Perhaps a moderate type of CI practice that increases acquisition performance but also encourages learning is the most beneficial type of schedule. However, little research has been done on various types of moderate CI schedules for children. Therefore, a transitional kind of practice schedule that incorporates a moderate CI effect that is beneficial to children needs to be examined. The common complaint among researchers that have not found a CI effect for children is that randomization overwhelms the learner in the beginning (Magill & Hall, 1990). With a transitional CI schedule the subject starts out by practicing repetitious blocks of one skill but the researcher will then slowly reduce the amount of trials in each block to the point of complete randomization. Perhaps a transitional schedule will work best for children because it will incorporate the blocking of practice early in acquisition but provide the necessary contextual interference later in order for learning during retention. There is a need for this study because motor control researchers have not yet examined a transitional CI schedule on children.

Assumptions

All participants will try to perform all tasks to the best of their abilities.

Delimitations

The author selected participants from the central coast of California and from youth activity leagues. The author selected children between the ages of 10 to 13 with a mean age of 11.5. There were a total of 36 subjects, half male and half female. All subjects were right handed.

Limitations

Due to convenience sampling for the selection process of the participants, there will be threats to our external validity. In addition to the sampling bias, the sample size and lack of representation of children from all economic backgrounds will limit our ability to generalize the results to the general population. Similarly, we will be unable to generalize our results to children that do not participate in youth sports.

Operational Definitions

Variability in practice: A prediction of schema theory; transfer is predicted to be facilitated when goals are systematically varied from trial to trial during practice (Schmidt & Lee, 2005).

Random practice: a practice sequence in which the tasks being practiced are ordered randomly across trials; high contextual interference (Schmidt & Lee, 2005).

Blocked practice: a practice sequence in which all of the trials on one task are done together, uninterrupted by practice on any of the other tasks; low contextual interference (Schmidt & Lee, 2005).

Transition practice: a practice sequence that starts out with trials of large blocks, then moves to smaller blocks, and eventually finishes with complete randomization.

Contextual Interference: the interference in performance and learning that arises from practicing one task in the context of other tasks (Schmidt & Lee, 2005).

Moderate CI: a practice schedule with small blocks of repetition randomly assigned to combine the benefits of both random and blocked practice.

Retention test: a performance test administered after a retention interval for the purpose of assessing learning (Schmidt & Lee, 2005).

Transfer test: refers to an experimental test where the subjects are tested in a different setting or on a slightly different skill than the first test in order to determine whether the initial learning was able to influence or contribute to learning in the new setting or on the new skill (Magill, 2007).

CHAPTER 2

Review of Literature

The purpose of this research was to examine whether a transition schedule would facilitate learning in retention and transfer equal to or better than random and blocked schedules among children performing a barrier knockdown task. The following chapter is a review of the relevant literature pertaining to past research on contextual interference. I organized the chapter by first reviewing William Battig's ideas on contextual interference and then reviewed Shea and Morgan's (1979) landmark study that expanded Battig's idea to the field of motor control. I then divided the literature review into two sections: researchers that examined forms of moderate contextual interference and researchers that examined how children respond to different practice schedules.

Battig

The contextual interference effect was first studied by William Battig in 1956, 1966, and again in 1972 with verbal learning experiments. However, it wasn't until his paper in 1979 where he expanded his ideas on contextual interference that the importance of his findings was finally recognized. In that paper, Battig explained that intertask interference that degraded performance during practice will often enhance learning during retention and transfer. Battig argued that intertask interference forced subjects to make a more elaborate and distinctive comparison between tasks and this led to a stronger memory representation of each task. While this would suppress performance during practice it would lead to increased performance during retention and transfer.

Battig identified two important factors that could lead to interference during practice: the types of motor behaviors to be practiced and the order in which they are practiced. Battig suggested that if the motor tasks to be practiced were quite similar, then the interference would be high but if the items or tasks were very distinct in nature then the interference would be low. In addition to the types of tasks, the order in which the subjects practice the task significantly affects interference as well. Battig stated that if subjects practiced the same task over and over before moving on to the next task, they need to hold only one motor pattern in working memory at a time and interference was low. However, when frequent switching between tasks occurred then the interference was high. Battig believed that subjects would respond to high or low levels of contextual interference with corresponding high or low levels of elaborative and distinctive processing and that the overall affect on learning would be significantly influenced.

Shea and Morgan

Shea and Morgan (1979) expanded Battig's ideas on contextual interference to the field of motor control. Their experiment included a barrier knock down task with seventy-two subjects who where assigned to one of two experimental groups based on either a random or blocked practice schedule. Each group practiced three variations of the task over a total of 54 acquisitions trials. The blocked group performed 18 trials of the first variation, followed by 18 trials of the second variation, and ended acquisition with 18 trials of the last variation while the random group practiced 3 blocks of 18 trials where each block consisted of all trial variations presented in a random order. The tasks involved rapid arm movements of three different patterns and were scored on movement time as well as reaction time. After acquisition, Shea and Morgan gave retention and transfer tests 10 minutes and 10 days later using both random and blocked conditions.

During acquisition, blocked practice resulted in an immediate performance advantage over random practice concerning total movement time (reaction time + movement time). Even though the performance gap between random and blocked practice groups was reduced over trials, the blocked group was performing significantly better in the last block of acquisition trials. However, during the retention phase, the results were reversed and the random group demonstrated a significant reduction in total movement time when compared with the blocked group. During the 10 minute retention test, the best performance was by the random group under the blocked schedule followed by the random group in the random presentation, then the blocked group in the blocked schedule, and the worst performance was the blocked group under the random schedule. The 10 day retention test yielded similar results with the only difference being that blocked group performed better under blocked conditions than the random group did under random conditions. In conclusion, the results to Shea and Morgan's experiment supports Battig's hypothesis, which states that high degrees of contextual interference initially degrade performance but will ultimately lead to enhanced learning.

While Shea and Morgan (1979) were able to demonstrate the contextual interference effect in a controlled laboratory setting, Hall, Domingues and Cavazos (1994) demonstrated the benefits of randomization and generalized it to field studies as well. The purpose of their study was to test contextual interfernce effects among skilled athletes hitting a pitched ball in baseball. The researchers randomly assigned thirty players from a local junior college baseball team to one of three groups; a random, a blocked, and a control group. Both the random and blocked group received 2 additional batting practice sessions each week for a 6 week period, while the control group received no extra batting practice. The control group took regular batting practice during the season as did the rest of the players. The extra session consisted of 45 additional pitches, 15 fastballs, 15 curves balls, and 15 changeups. The blocked group received all 15 pitches of each variation in a block before moving on to the next variation while the random group practiced all pitches in a random fashion. The random group did not receive any specific pitch more than twice in a row. Two coaches from the subject's team evaluated the quality of the hit and labeled each hit as solid or not solid. A solid hit was defined as one that would most likely be a successful hit in a game. All three groups received a random pretest of 45 pitches consisting of each pitch variety. After 6 weeks, all groups participated in 2 transfer tests; one presented randomly and the other blocked for the three pitches variations.

During the pretest analysis, none of the three groups demonstrated a significant difference in their ability to get a solid hit. However, after the 6 week period, both the random and blocked group performed significantly better than the control group which received no additional practice and the random group was significantly better than the blocked group. Comparing just the pretest to the post test scores, the random group improved 56.7% while the blocked group only improved 24.8% from their pretest score. While blocked practice is better than no practice at all, these findings clearly suggest that a contextual interference effect is robust and beneficial to skilled athletes in a sport setting such as batting.

Moderate CI

In an early review of contextual interference literature, Magill and Hall (1990), suggested that a high degree of contextual interference, like what Hall, Domingues, and

Cavazos (1994) found in the baseball study, may actually overwhelm learners in the early stages of skill acquisition and negate any benefits that randomization could offer. Pigott and Shapiro (1984) were one of the first to suggest that a lower CI level consisting of small blocks may enhance learning for children and beginners while a high CI level may create too much interference and actually hinder learning. They conducted a study examining 32 male and 32 female students ranging from 6 years to 8 years of age. The subjects were assigned to four groups, where each group was balanced for age and sex. The task was for the children to throw different weighted beanbags at an inclined target 183 cm away. There were a total of 6 bean bags, weighing either 2 oz.; 3 oz; 4 oz; 5 oz; 6 oz; and 7oz. All groups received 24 trials, where three of the groups experienced throwing bean bags of 4 different weights. There was a control group that just practiced all 24 trials with the same weight. Of the 3 variable groups, there was a random group that practiced with a different weight from trial to trial. A random-blocked group repeated a session where they practiced with the same weight for 3 trials before they randomly switched to a new weight for three more trials. The final group practiced under a larger blocked schedule where they practiced 6 trials with same weight before transferring to a new weight. Following the acquisition stage, all subjects immediately transferred to three test trials where they either threw a 2 oz. or 7 oz. bean bag.

During acquisition, the random group consistently made the most errors; however, the group that made the least errors was the random-blocked group. Traditionally, the blocked groups perform the best during acquisition as they have the most opportunity for error correction but then during retention and transfer they demonstrate lower levels of learning. During transfer, the blocked-random group also performed significantly better than the other 3 groups which did not differ from each other. Therefore, the group which performed under a moderate form of contextual interference not only was best during acquisition but also best during transfer. It is important to note that while this seems to contradict Battig and lend minimal support to his contextual interference theory, the size of the blocks of trials used in this study probably do not represent the ends of the continuum for contextual interference. The random-blocked group in this study practiced blocks of 3 trials which is very close to randomization and should not be considered a middle of the continuum schedule. Similarly, blocks of 6 do not represent a low contextual interference practice schedule and should be considered more of a moderate schedule. In conclusion, Pigott and Shapiro merely suggest that small blocks of tasks appear to facilitate learning of a bean bag toss in young children. While Pigott and Shapiro argue that their results provide minimal support for contextual interference, the design of the experimental groups does not accurately represent the ends of the contextual interference continuum and therefore further research testing moderate groups of contextual interference is needed.

In 1993, Al-Ameer and Toole found similar results in support of Pigott and Shapiro (1984). In this study, participants learned barrier knock down task similar to that in Shea and Morgan's (1979) task. The purpose of their experiment was to test the effects of combining blocked and random practice in order to create less interference during acquisition but still enough to benefit retention. Researchers randomly assigned thirty-six subjects to one of four treatment groups; blocked practice (BP), random practice (RP), randomized blocks of two trials (RB2), or randomized blocks of 3 trials (RB3). During acquisition, each subject performed a total of 54 trials of 3 different patterns on the Genshute Apparatus which was similar to the barrier knockdown test used in the Shea and Morgan (1979) study. The blocked group practiced one pattern for 18 trials before moving on to the next pattern while the random group practiced all three patterns in a complete random fashion. The RB2 group practiced 2 trials of one pattern, 2 trials of the next pattern, and then 2 trials of the last pattern before being randomly switched to a new block of trials. The RB3 group was exactly the same as the RB2 group but they performed 3 trials instead of 2 before moving on to the next pattern. Al-Ameer and Toole tested each subject on their reaction as well as total movement time. The subjects received a 10 minute rest and were retested on 24 trials (8 trials of each pattern) administered in a random order.

During acquisition, the RB3 group performed just as well as the blocked group and both were significantly better than the all random and RB2 groups. Most importantly, the RB3 group was also just as good as the random and RB2 groups during retention while the blocked group was significantly slower in reaction and movement time. The RB3 group, although very close to randomization on the CI continuum, was the most moderate form of contextual interference in this study and created an optimal amount of interference that produced the best acquisition and retention score. The authors concluded that the subjects were able to use feedback from their first two trials to improve and plan for their upcoming movement in their final trial of each block. This process helped improve the acquisition score in comparison to the random group. However, the subjects also had to retrieve a new movement plan at the end of each 3 trial block and this process most definitely benefited retention but was not enough to cause acquisition decrements. Their final conclusion was that the small blocks of trials facilitated error correction during acquisition but still provided the necessary interference by changing tasks often enough to enhance learning in retention. Just as in the Pigott and Shapiro (1984) study, it is important to note the RB3 group is really not a middle of the continuum schedule but rather much closer to randomization than blocked. Small blocks of trials produced the best results in this barrier knock down task but further research is needed to test the middle of the CI continuum in the applied setting.

Landin and Hebert (1997) continued the research on examining the moderate contextual interference practice schedule notion applied to the field of basketball shooting. While the CI effect is rather consistent and robust in the lab, it can be difficult to replicate in the field. Therefore, Landin and Hebert's stated purpose was to test the effectiveness of a moderate CI schedule among 30 undergraduate college students who had played 2 years of high school basketball. On day 1, the subjects were pre-tested on set shots from 3 different locations on a standard basketball floor. They shot 5 balls from each location for a total of 15 trials. Researchers evaluated on the percent of successful makes and randomly assigned the subjects to one of three groups: low, moderate, and high CI.

The subjects practiced for a total of three days and performed a total of 30 trials each day. Each subject shot 5 balls from a total of 6 different locations on the floor. Participants practicing under a high CI schedule shot one ball from each location in a serial arrangement repeating this procedure six times. The group participating under a moderate CI schedule performed 3 trials at each location and repeated this sequence twice. Those practicing under the low CI schedule shot 6 balls from each location before moving on to the next and did this only once.

Landin and Hebert assessed learning through three counterbalanced retention tests. The first retention test consisted of a single 12 trial blocked test from three separate locations on the floor. The second test was a 12 trial serial test from the same three locations as the blocked test. The final retention test was a 10 trial free throw test performed in 2 trial sequences. During acquisition, none of the three groups were significantly different which is contrary to most laboratory research where the low CI group usually performs the best. However, during retention, the moderate CI group demonstrated a significant improvement compared to both random and blocked. Landin and Hebert concluded that moderate levels of CI may be superior to the extreme ends of the continuum especially in an applied setting such as basketball. Their explanation for the success of a moderate CI practice schedule was consistent with that of what past researchers have concluded (Pigott & Shapiro, 1984: Proteau, Blandin, Alain, & Dorion, 1994). They argued that small blocks of trials offer the participant the opportunity to make adjustments for one task but yet still offers enough interference by requiring them to perform several tasks during each session. The authors did not give a random retention test and they considered the group that practiced under blocks of 6 trials as the low CI group. However, this group is really more toward the middle of the continuum considering that Shea and Morgan used blocks of 18 as their blocked group. Although Landin and Hebert called their small blocks of 3 trials, moderate, they were really closer to the high CI end of the continuum than the middle.

In a 2007 study Porter, Landin, Hebert, and Braum, concluded that a higher degree of contextual interference is more beneficial to retention than a middle of the road practice schedule. The purpose of their study was to measure the effect three different levels of contextual interference had not only on performance outcomes of a golf putt and chip but also on the movement patterns of those strokes. The researchers selected twenty-three college aged students with no golfing experience to perform a basic putt and pitch shot pre test. Researchers gave scores based upon how far away each shot finished from the hole, with a higher score for closer shots. On day two, all participants performed 160 trials under a low, moderate, or high contextual interference setting. The low CI group performed 80 putts and then 80 chips while the moderate group performed 10 putts and then 10 chips and repeated this 8 times. Finally, the high CI group alternated between putting and chipping for a total of 160 trials.

The high CI group demonstrated superior results in all post tests in comparison to the moderate and low CI groups. Unique to this study was also the analysis of the improvement of movement patterns from pretest to posttest. Again, the high CI group demonstrated superior improvement to the other three groups. Unlike other researchers that tested a moderate form of contextual interference, Porter et al. concluded that it was not the best for learning. They strongly suggest randomizing practice schedules in regards to beginners in the field of golf.

Compared to blocked practice, high and medium levels of contextual interference produce a more robust learning effect but it is still unclear whether the same can be said when dealing with children. Past researchers (Magill & Hall, 1990; Pigott & Shapiro, 1984) has suggested that the benefits of high contextual interference usually seen among adults may not be the same for children. Research focusing primarily on randomization's effect on children was lacking throughout the 1990's but has since gained momentum and researchers have more knowledge now than ever before.

Children

In 2003, Vera and Montilla examined the contextual interference effect among young children. Sixty-one children performed a pretest in which they threw a tennis ball and a feather fly ball at two separate targets; one horizontal laying on the ground and another vertical up against the wall. The subjects performed 20 throws total, 10 from 3 m away and 10 from 5 m away. The researchers divided up the 61 subjects into either a blocked or random group. During acquisition, the blocked group practiced these trials over a 6 week period varying one parameter after every 5 trials in a blocked fashion. The random group performed the same trials but one parameter was modified on each throw, i.e., the type of ball, the distance to the target, and the location of the target. Researchers conducted a retention test at the end of the 6 week practice session in addition to a transfer test where the type of ball and distance to the target was changed. The random group performed better on both the retention and transfer tests, supporting the CI effect among children. The high CI random practice did not overwhelm the children but rather the extra processing enhanced learning.

Vera and Montilla (2003) also point out that short practices may negate any differences between blocked and random groups. In their study, they had child subjects practice over a 6 week period in order to emphasize or highlight any difference between the two groups. They argued that practice must last long enough for true learning to be consolidated. Motor skills take years to learn and longer practice sessions would replicate more real world settings. A good example of what Vera and Montilla explained can be seen with a 1999 study by Jarus and Goverover.

Jarus and Goverover (1999) investigated the varying conditions of contextual interference within three age groups. Their experiment was very similar in design and purpose to the Vera and Montialla's 2003 study. Subjects were forty 5-year olds, forty 7-year olds, and forty 11-year olds. They practiced throwing bean bags under either low contextual interference (blocked practice), high contextual interference (randomized practice), or medium contextual interference (combined practice) onto three large circled targets drawn on the floor. Subjects in the blocked practice group practiced in blocks of 10 while the moderate group practiced in blocks of 4. The random group performed 30 total trials randomly switching between the three targets and never repeating any target more than twice. The authors not only wanted to test the CI effect among different age groups but also wanted to test the effect of a moderate form of interference. Each group performed 30 acquisition trials, 12 retention trials, and 6 transfer trials.

Only the 7-yr old groups differed in their performance in the various practice groups. They performed better in acquisition and retention in the blocked and combined practice groups than in the randomized schedule. Interestingly, none of the other two age groups performed significantly better under any of the three conditions during the retention or transfer tests. It would appear that either the 7-yr group is at a particular age where blocked is more beneficial than random practice or that the acquisition stage was too short to get any conclusive data. There is also the chance that this particular group was the only one with enough power to find significance. As Vera and Montilla would later suggest, randomization among children can be more successful than blocked practice but the acquisition period must be long enough to consolidate the learning that takes place. Clearly, the 30 acquisition trials completed in this study was not long enough to test the contextual interference effect and more studies are needed to verify what Vera and Montilla (2003) found.

In a recent study, Zetou, Michalopoulou, Giazitzi, & Kioumourtzoglou (2007), examined the difference between a low and high contextual interference effect on learning volleyball skills in 26 novice female players with an average age of 12.4 years. The authors randomly divided the subjects into two groups, blocked and random, to test learning. Subjects received the American Association for Health Physical Education and Recreation skills test that included the set, serve, and pass as a pretest before the 10 weeks of practicing took place. Immediately following the final practice session, the subjects took the same AAHPER's skill test as part of a posttest to measure improvement. Subjects took a retention test two weeks later to measure learning. During practice sessions, the subjects performed a total of 270 trials, 90 serving, 90 setting, and 90 passing. The blocked group performed each skill 90 times before moving on to the next skill, while the random group practiced each skill in an unpredictable random order, never repeating one skill more than twice in succession.

Each group demonstrated significant improvement in performance from their pretest to posttest scores in each skill but no significant difference between the groups was present at the end of acquisition. Similarly, learning of the three volleyball skills was demonstrated in retention but again the groups did not show a significant difference. The authors believed that perhaps the skill level of the subjects were too low in order to benefit from a high contextual interference situation. Landin and Hebert (1997) had concluded that age, skill, and the complexity of the task all interact with practice schedules to produce a contextual interference effect. They believed that it was better to combine low and high levels of CI in practice to enhance learning. Zetou et al. concluded that either a blocked or random practice schedule could be effective for teaching volleyball to unskilled children and that more studies were needed.

Laura and French (2007) did a similar study to Zetou et al. (2007) but added a third practice schedule that created an interference effect in the middle of the CI continuum. The authors measured the performance of learners practicing the AAHPERD volleyball skills test (serve, forearm pass, set) when the change in task presentation varied. Sixty-eight 9th grade high school students were randomly selected and assigned to one of three practice groups; blocked, random, and random-blocked. Acquisition lasted for a total of 9 days with each day consisting of a total of 30 trials. The sum of the first 10 trials everyday consisted of the pretest while the last 10 trials every day consisted of the posttest. The blocked group practiced one skill for 3 straight days before changing to a different skill. The random group also practiced 30 trials a day but all three skills were practiced on the same day, in a random order, with no skill repeated more than twice. The random-blocked group practiced all three skills in the same day but practiced each skill in blocks of 10 trials. After the end of 9 days, the subjects rested for 2 days and came back and performed a retention test that followed the protocol for the AAPHERD volleyball skills test.

As with the Zetou et al. (2007) study, all three groups significantly improved their skills from pretest to post-test but there was no support for the contextual interference effect. Also, similarly to Zetou et al. (2007), Laura and French (2007) found no statistical difference among the three groups during retention. One explanation for why no difference among the groups might be that the type of tasks practiced were too different and thus the difference in skills required to perform a serve, bump, and set may be too varied and would negate any benefits of a randomized practice schedule. Also, the learner's skill as well as the complexity of the task might be independent variables that researchers must control in order to accurately test for the contextual interference effect.

Ste-Marie, Clark, Findlay, & Latimer (2004) examined the effects of high contextual interference on a much less complex task than volleyball skills. The authors examined handwriting skill among elementary school students. They conducted 3 experiments using 172 subjects ranging in age from 5 to 7. In the first experiment, the authors randomly assigned the students into one of two groups: blocked or randomized. In the blocked groups, the students practiced handwriting either *h, a,* and *y* consecutively 24 times before moving on to the next letter. In the randomized group, the subjects practiced the same letters but in a completely random order and never practiced the same letter more than three consecutive times. There were a total of 72 trials. Both groups received feedback intermittingly throughout the acquisition phase. The researchers then randomly assigned the children into either a random or blocked retention test.

Results demonstrated that success among the groups varied greatly in the acquisition stage but the random groups as a whole performed significantly better on the retention tests compared to the blocked groups. As opposed to the volleyball studies where the tasks were varied, complex and gross in nature, these authors tested the CI effect on fine motor tasks that were similar in their motor pattern. There seems to be a relationship between the success of contextual interference on learning and the type of motor task. Because these studies were performed using children subjects, the authors were able to generalize that using high degrees of contextual interference among children is a viable option to enhance the learning of handwriting skill.

The contextual interference effect needs more research not only concerning children but also with more moderate forms of practice schedules. While randomization has shown to enhance learning in both the field and laboratory setting, it also been no better than blocked in other cases and even overwhelmed children in early stages of development. Although some of the research focusing on the middle of the continuum contextual interference has had faulty designs and methods, the idea of a more moderate practice schedule is intriguing nonetheless. A moderate schedule may keep the learner from being overwhelmed in the acquisition stages but could possible offer the same learning effects as randomization. A transition schedule, a type of moderate interference, which starts the subjects out in big blocks but slowly moves them toward randomization, may offer the subjects the best results in both acquisition and retention but needs more research.

Chapter 3

Methods and Procedures

Purpose

The purpose of this study was to examine whether a transition schedule of contextual interference would facilitate learning in retention and transfer equal to or better than random and blocked schedules among children.

Participants

Researchers selected participants from youth activity leagues in the central coast of California. All participants were between the ages of 10 and 13 and the entire group had a mean age of 11.5. There were a total of 36 subjects, half male and half female. Unfortunately, due to computer error, only data from 15 subjects were saved and available for analysis. All participants were right handed. The parents all completed consent forms explaining the procedures and possible risks. Researchers randomly assigned participants to one of three groups: the random group, the blocked group, or the transition group. Researchers promised all participants an ice cream sandwich upon completion of both retention and transfer tests.

Apparatus

Researchers used a large wooden barrier knock down apparatus similar to the one used in the Shea and Morgan (1979) study. The wooden base of the apparatus sat on a table at about the subject's waist line and extended back about 3 feet. There were 6 padded barriers standing parallel to each other, with 3 barriers on each side of the base. A vertical wooden backboard was attached to the back of the platform and contained two sets of four warning lights: blue, red, green, and white. Task cards sat below the warning lights indicating a particular pattern that the subjects followed. The barriers fell outwards when struck by the subject. A start button was located between the first two barriers and a finish button was located between and slightly behind the last two barriers. A computer attached to the knock-down apparatus recorded reaction and movement times.

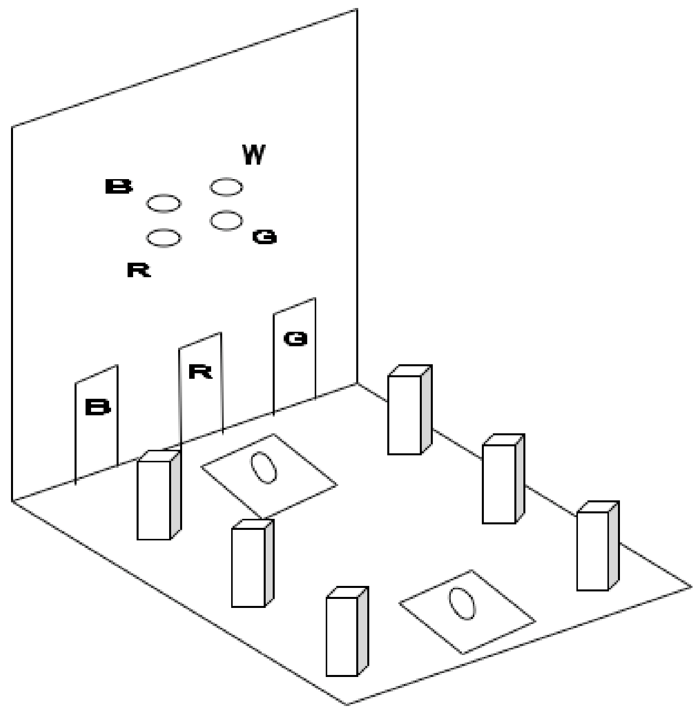


Figure 1. The barrier knockdown apparatus

This is the classic contextual interference apparatus used to test for differences in reaction and movement time. However, to the best of our knowledge, this apparatus has never been used to test children due to the complexity and difficulty of getting children to a laboratory setting. Therefore, there is a specific need for this study in order to examine the contextual interference effect among children in the same setting as researchers usually test adults.

Procedure

The subjects held down the start button once they heard a warning buzzer. The subjects then waited for a cuing light that indicated what pattern to follow. When the start light came on, the subjects released the start button, knocked down the barriers according to the specified pattern on the task card, and finally pressed the stop button near the end of the platform. Researchers recorded reaction time and movement time. This process concluded one full trial. When the subject made an error with regards to the pattern, then the researchers discarded the data for that trial and the participants repeated the trial at the end of acquisition.

The researchers used three practice groups for this qusai-experiment: a random group, a blocked group, and a transition group. Each group performed 60 trials during the acquisition phase and practiced a total of 3 different arm patterns. All three groups practiced each pattern a total of 20 times during acquisition. The random group practiced each pattern in random fashion such that no one pattern was repeated more than twice in a row. The blocked group performed 20 trials of the green pattern, followed by 20 trials of the blue pattern, and lastly 20 trials of the red pattern. Researchers counterbalanced the blocked group so that one-third of the group performed acquisition in a green, blue, red rotation. Another one-third of the group performed 20 trials of each color pattern but started with the blue pattern, followed by the red, and lastly the green. The remaining one-third of the blocked group practiced 20 red patterns, 20 green patterns, and finally 20 blue patterns. The transition group performed the first 24 trials in a blocked fashion, that is 8 trials of the green pattern were practiced, followed by 8 trials of the blue pattern, and then 8 trials of the red pattern. The group then practiced smaller blocks and performed 5 trials of each color. Another 9 trials were performed in a blocked fashion with 3 trials of each pattern. The final 12 trials were presented randomly to this group.

Following acquisition, participants took an immediate retention test that was counter balanced following a 10 minute rest. The retention test consisted of 9 random trials of the three various patterns. Researchers gave a transfer test following the retention test, which consisted of six trials of a novel (white) pattern. During the transfer test, a task card with the white pattern was placed on the middle hook and a white stimulus light was used. Researchers tested all three groups one week later with a delayed retention and transfer test similar to the tests described above.

Design

Researchers used a quasi-experimental design where the dependent variables were reaction and movement time with the independent variable being the type of practice schedule.

Analysis of Data

In retention, researchers used a one-way ANOVA to examine if there was a difference in levels of learning due to practice schedules. The same test was used for the transfer, delayed retention, and delayed transfer tests.

Alpha was set at .05. When researchers found a significant F, we used a follow-up Tukey Post Hoc Analysis with multiple comparisons to determine the differences in learning among the groups.

Chapter 4

Results

Analysis of the Data

The dependent measures included reaction time and movement time (measured in milliseconds). Researchers collected acquisition data but did not analyze it. Researchers analyzed the data using a one-way ANOVA for both retention and both transfer tests. The alpha level was set to 0.05 for all analyses. All error trials were removed from the data set before analysis but were analyzed separately in order to gain information about errors across the three separate groups. When a significant F ratio was found, researchers used Tukey's Post Hoc Analysis to determine where the differences were located.

Results

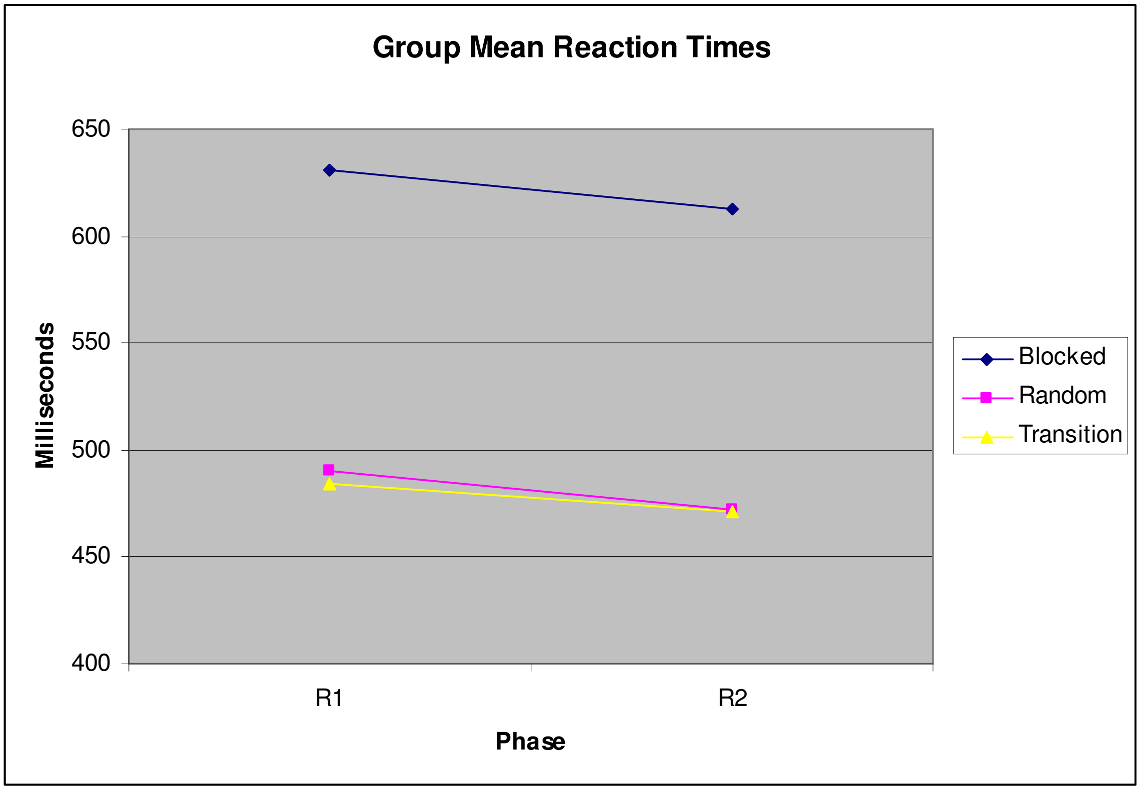
<u>Retention 1 (Immediate) Reaction Time</u>

Researchers found no significant difference ($F=2.21$; $p=0.152$) using the one-way ANOVA, however the blocked group demonstrated a slower mean score in reaction time compared to both the random and transition groups (see chart 1).

<u>Retention 2 (Delayed) Reaction Time</u>

Researchers found no significant difference ($F=3.66$; $P=0.058$) using the one-way ANOVA, however both the random and transition groups had a much faster reaction time than the blocked group, just missing significance (see chart 1).

Chart 1



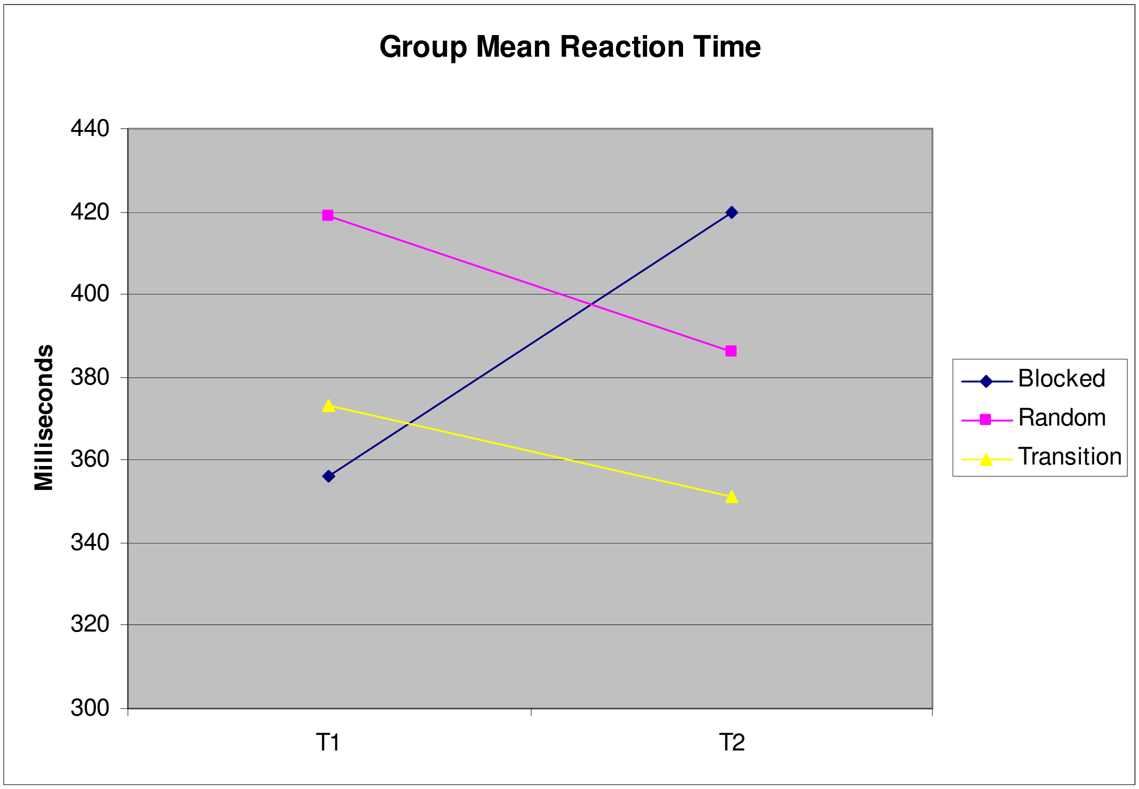
Transfer 1 (Immediate) Reaction Time

Researchers found no significant difference (F=.65; P=0.540) using the one-way ANOVA. There was very little difference between the mean scores to even suggest a trend (see chart 2).

Transfer 2 (Delayed) Reaction Time

Researchers found no significant difference (F=.61; P=0.558) using the one-way ANOVA, however the trend of the blocked group having the slowest reaction time, while the transition and random group having the fastest reaction time continued with this analysis (see chart 2).

Chart 2



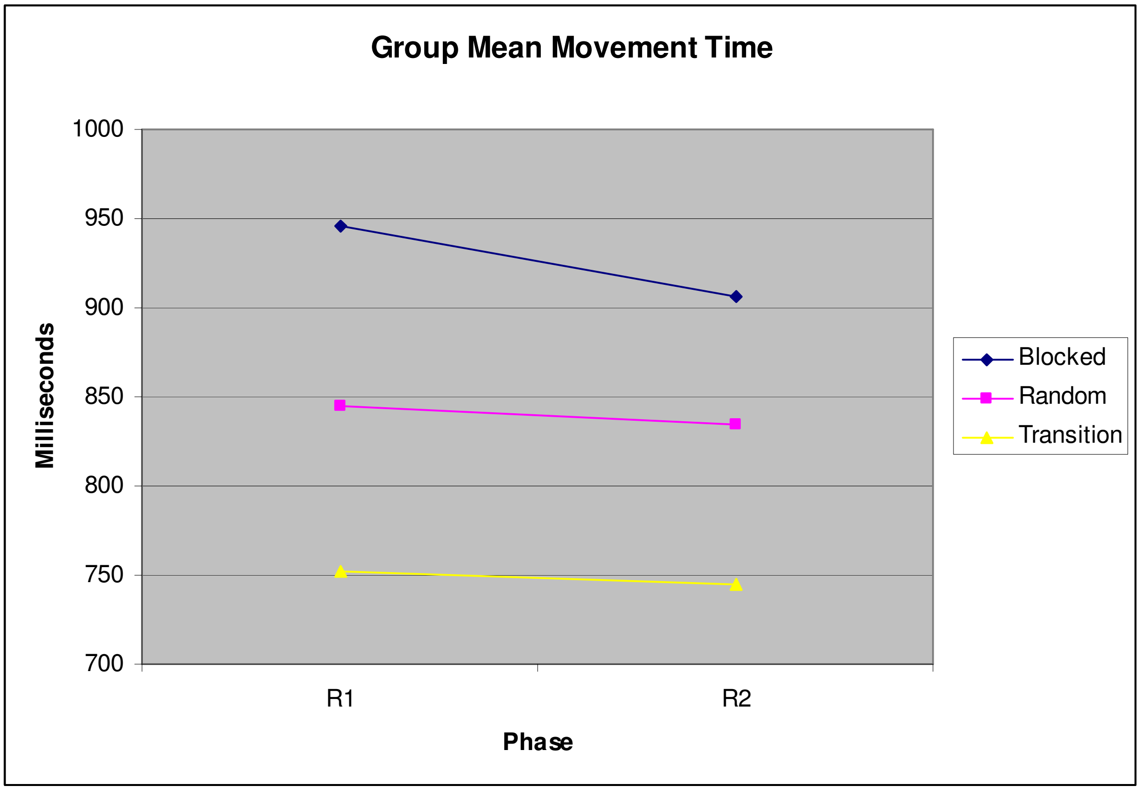
Retention 1 (Immediate) Movement Time

Researchers found no significant difference (F=2.92; P=0.092) using the one-way ANOVA. However, the trend in the data was that the blocked group had the slowest movement time and the transition group had the fastest movement time but neither of the mean movement times was great enough for significance (see chart 3).

Retention 2 (Delayed) Movement Time

One-way ANOVA analysis of the data revealed a significant difference (F=4.28; P=.039). The follow up Tukey Post Hoc Analysis test demonstrated that the transition group had a significantly faster movement time than the blocked group but that random group was not significantly different from either the blocked or transition group (see chart 3).

Chart 3



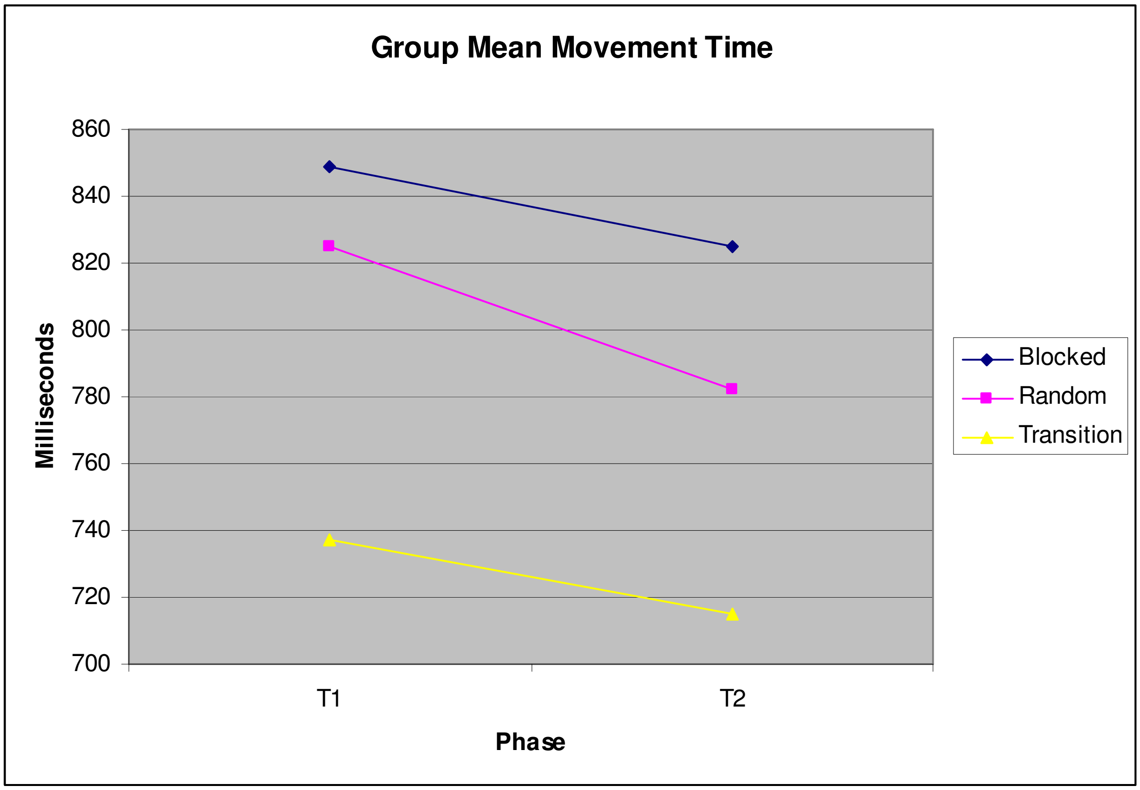
Transfer 1 (Immediate) Movement Time

Researchers found no significant difference (F=1.39; P=0.287) using the one-way ANOVA. The transition group had the fastest mean times of all groups but was not significantly faster than the other two (see chart 4).

Transfer 2 (Delayed) Movement Time

Researchers found no significant difference (F=1.91; P=0.191) using the one-way ANOVA, however the same trend continued where the random group had a faster movement time than the blocked group but not a faster time than the transition group (see chart 4).

Chart 4



Errors for all tests

Table 1

Group	Count
Blocked	34
Random	16
Transition	34
Total=	84

The random group committed the fewest amount (16) of errors total over the 4 learning tests while both blocked and transition committed 34 errors. While errors are not necessarily an indicator of learning they are an indicator of cognitive confusion. Considering that the random and transition group consistently performed better than the blocked group during retention and transfer for both reaction and movement time, it was somewhat surprising that the transition group made so many errors. However, one subject in the transition group committed 14 errors by themselves and this greatly affected the data due to the small sample size.

Discussion of the Findings

We examined the learning effects of three different practice schedules when learning a barrier knockdown apparatus. The findings indicated that there was no significant difference among the three groups during any of the transfer tests. Similarly, there was no significant difference among the groups for reaction time during the two retention tests, although there was a noticeable trend that both random and transition groups had a much faster reaction time than the blocked group just missing significance (P=.058). However, there was a significant difference in total movement time during the delayed retention test. The transition group had a significantly faster movement time than the blocked group demonstrating a CI learning effect while the random group was not significantly different than either group. However, the random group did have a faster mean movement time than the blocked group which supports previous research (Shea & Morgan, 1979, Lee & Magill, 1983, Magill & Hall, 1990). Ultimately, the transition and random groups compared to the blocked group, were the only groups to benefit from the CI effect because their practice schedules created a disruption or interference which caused a context free environment for the skills to be learned.

The results of this study support our hypothesis that a transition type of practice schedule can be equal to a random schedule but superior to blocked practice. A transition group has not been examined in past literature so there is no comparison to make, however many types of moderate groups have been tested and a transition group is a type of this middle of the continuum group. Many researchers (Pigott & Shapiro, 1984, Al-Ameer & Toole 1993, Landin & Hebert, 1997) have argued that a moderate schedule is the best of both worlds. They have explained that the small blocks initially do not degrade acquisition but that there is enough random presentation of tasks to facilitate the CI effect. This argument can also be used in support of the transition practice schedule because the real benefit to a transition schedule is that the subjects start out blocked in order to reduce the chance of overwhelming a beginner; especially important with children, but finish practice with randomized trials in order to enhance learning. It was not surprising that during immediate retention and transfer, neither random or transition was significantly different than blocked because there was not enough time between the last acquisition trial and the test for learning to consolidate. However, a week later during the delayed retention test, random and transition just missed being significantly better than blocked with regards to reaction time and the transition group had a significantly faster movement time than the blocked group.

Although researchers found no significance during the transfer tests due to the smaller sample size, there was definitely a trend with the mean group times. During the delayed transfer tests for both reaction and movement time, the blocked group always had the slowest times, the transition group always had the fastest times, and the random group was in between. With such a small sample size, finding significance would have been rare, so analyzing the trends can be quite important for encouraging further research in this area.

Chapter 5

Conclusion

Summary

The purpose of this research was to examine whether a transition schedule would facilitate learning in retention and transfer equal to or better than random and blocked schedules among children performing a barrier knockdown task. The apparatus was similar to the one used by Shea and Morgan (1979) in their landmark study that revealed randomization to be a superior practice schedule compared with blocked. However, not all researchers have found random schedules to be a superior practice schedule to blocked and some (Magill and Hall, 1990) even argue that random schedules can overwhelm beginners and children. Even when researchers have demonstrated contextual interference to be a robust effect, some theorists have expressed a concern that any practice schedule that suppresses performance during practice may not be well received by athletes, parents, coaches, or managers, and therefore the task may be terminated due to lack of early success. Therefore, it was important to test a transition practice schedule that started subjects out in a blocked schedule in order to avoid overwhelming the child but transitioned into a randomized practice schedule in order to take advantage of the contextual interference learning effect. The findings were that transitional group had a significantly faster movement time than the blocked group during the delayed retention test but was not significantly different on any of the other retention or transfer tests. Although no literature exits on transition groups, this is consistent with past CI literature (Pigott & Shapiro, 1984, Al-Ameer & Toole 1993, Landin & Hebert, 1997) where researchers have argued in support of a more moderate form of contextual interference.

Conclusions

Transitioning from a blocked practice schedule to a random schedule appears to be significantly better than blocked by itself and an effective alternative to strictly random schedules. Although the transition group demonstrated a significantly faster movement time than the blocked group only on the delayed retention test, the trend in the data for immediate retention and delayed transfer suggests that the transition schedule facilitated a deeper level of learning compared to blocked practice schedules. On these two tests, the random group demonstrated faster movement and reaction times than the blocked group and the transition group usually demonstrated even faster times than the random group.

The delayed retention test was the only learning test to reach significance. Both the immediate retention and transfer tests took place after acquisition and there was not enough time for learning to be consolidated, thus no significant differences in learning levels were found. However, during delayed retention, the transition group demonstrated to be significantly different from the blocked group because the one week delay from the last trial in acquisition to the retention test provided enough time for learning to be measured.

A limitation to this study was the small number of subjects per group. With only 5 children per group, a significant difference between groups was unlikely due to the lack of power. With only 5 subjects, the likelihood that one subject could skew the data is much more likely than had there been 12 subjects per group. In a 5 subject group, each child has more power to affect the results and it is possible some groups could have children with more developed motor skills. Thus, finding significance with a 5 subject group is rare but also quite meaningful because we can be certain that the transition practice schedule can enhance learning.

Recommendations

Based on the findings of this study, there are two areas of recommendations. The first area is that more research needs to be conducted with a significantly larger sample size. The trends in the data suggest that a transitional schedule can facilitate learning equal to random practice schedules and be significantly better than blocked schedules and a larger sample size would highlight these differences. In addition to replicating this study with a larger sample size, the second area of recommendation would be to conduct further research into middle of the continuum groups. Experimenting by changing the size of the blocks in the transition schedule could yield significant differences between the practice schedules. In addition to changing the sizes of the blocks, other modifications in the schedule could be examined such as starting the subjects out completely blocked, then switching them to a completely random schedule, then back to a blocked schedule, and finishing with a random schedule. This schedule would be more practical and probably easier to replicate in a real world setting. For instance, it would be rather difficult for a baseball coach to remember exactly how many and what pitches he had thrown to a certain batter to stay true to the transition schedule. However, throwing the same pitch over and over and then switching to a random schedule would be easier to keep track of while he helped his batters with their technique. Also, the transition practice schedule should be researched using field tasks such as baseball hitting, volleyball skills and basketball shooting to see if the contextual interference effect can be generalized to real world settings.

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Appendices

Appendix A

One-way ANOVA Results

Results for: subjectmeans(Task = R1)

One-way ANOVA: AverageReaction versus Group

```
Source  DF      SS     MS     F      P
Group    2   52871  26435  2.21  0.152
Error   12  143421  11952
Total   14  196291

S = 109.3   R-Sq = 26.93%   R-Sq(adj) = 14.76%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N   Mean  StDev  --+---------+---------+---------+-------
1      5  613.1  127.4              (---------*----------)
2      5  490.0   97.7  (----------*----------)
3      5  484.4  100.4  (---------*----------)
                        --+---------+---------+---------+-------
                        400       500       600       700

Pooled StDev = 109.3


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 97.94%


Group = 1 subtracted from:

Group   Lower  Center  Upper    -+---------+---------+---------+--------
2      -307.4  -123.1   61.2     (-----------*-----------)
3      -312.9  -128.6   55.7    (-----------*------------)
                                -+---------+---------+---------+--------
                              -300      -150         0       150


Group = 2 subtracted from:

Group   Lower  Center  Upper    -+---------+---------+---------+--------
3      -189.9    -5.5  178.8            (------------*-----------)
                                -+---------+---------+---------+--------
                              -300      -150         0       150
```

Results for: subjectmeans(Task = R1

One-way ANOVA: AverageMovement versus Group

```
Source  DF      SS     MS     F      P
Group    2   94514  47257  2.92  0.092
Error   12  194003  16167
Total   14  288516

S = 127.1   R-Sq = 32.76%   R-Sq(adj) = 21.55%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N   Mean  StDev  --------+---------+---------+---------+-
1      5  946.8  140.8                   (---------*---------)
2      5  845.5  113.2          (---------*----------)
3      5  752.4  125.9  (----------*---------)
                        --------+---------+---------+---------+-
                              720       840       960      1080

Pooled StDev = 127.1


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 97.94%


Group = 1 subtracted from:

Group   Lower  Center  Upper     +---------+---------+---------+---------
2      -315.6  -101.2  113.1         (----------*----------)
3      -408.8  -194.4   20.0     (---------*----------)
                                 +---------+---------+---------+---------
                              -400      -200         0       200


Group = 2 subtracted from:

Group   Lower  Center  Upper     +---------+---------+---------+---------
3      -307.5   -93.1  121.2          (---------*----------)
                                 +---------+---------+---------+---------
                              -400      -200         0       200
```

Results for: subjectmeans(Task = R2)

One-way ANOVA: AverageReaction versus Group

```
Source  DF      SS     MS     F      P
Group    2   66181  33091  3.66  0.058
Error   12  108589   9049
Total   14  174771

S = 95.13   R-Sq = 37.87%   R-Sq(adj) = 27.51%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  --+---------+---------+---------+-------
1      5  613.08  122.49                (--------*---------)
2      5  472.90   73.86  (--------*---------)
3      5  471.46   81.78  (--------*--------)
                          --+---------+---------+---------+-------
                          400       500       600       700

Pooled StDev = 95.13


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 97.94%


Group = 1 subtracted from:

Group    Lower   Center  Upper  -----+---------+---------+---------+----
2      -300.56  -140.18  20.20  (------------*-------------)
3      -302.00  -141.62  18.76  (------------*-------------)
                                -----+---------+---------+---------+----
                                  -240      -120         0       120


Group = 2 subtracted from:

Group    Lower  Center   Upper  -----+---------+---------+---------+----
3      -161.82   -1.44  158.94             (------------*------------)
                                -----+---------+---------+---------+----
                                  -240      -120         0       120
```

Results for: subjectmeans(Task = R2)

One-way ANOVA: AverageMovement versus Group

```
Source  DF      SS     MS     F      P
Group    2   65249  32625  4.28  0.039
Error   12   91416   7618
Total   14  156665

S = 87.28   R-Sq = 41.65%   R-Sq(adj) = 31.92%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level  N    Mean   StDev  ----+---------+---------+---------+-----
1      5  906.24  122.84                 (--------*-------)
2      5  834.62   60.76          (-------*--------)
3      5  745.02   63.82  (--------*-------)
                          ----+---------+---------+---------+-----
                            700       800       900      1000

Pooled StDev = 87.28


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 97.94%


Group = 1 subtracted from:

Group    Lower   Center   Upper    -+---------+---------+---------+--------
2      -218.78   -71.62   75.54          (---------*---------)
3      -308.38  -161.22  -14.06    (---------*---------)
                                   -+---------+---------+---------+--------
                                 -300      -150         0       150


Group = 2 subtracted from:

Group    Lower  Center  Upper    -+---------+---------+---------+--------
3      -236.76  -89.60  57.56        (---------*---------)
                                 -+---------+---------+---------+--------
                               -300      -150         0       150
```

Results for: subjectmeans(Task = T1)

One-way ANOVA: AverageReaction versus Group

```
Source  DF      SS    MS     F      P
Group    2   10644  5322  0.65  0.540
Error   12   98321  8193
Total   14  108966

S = 90.52   R-Sq = 9.77%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  -----+---------+---------+---------+----
1      5  356.92   39.81  (-------------*--------------)
2      5  419.88  148.97            (--------------*--------------)
3      5  373.56   28.37     (-------------*--------------)
                          -----+---------+---------+---------+----
                             300       360       420       480

Pooled StDev = 90.52


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 97.94%


Group = 1 subtracted from:

Group    Lower  Center   Upper  -------+---------+---------+---------+--
2       -89.65   62.96  215.57            (------------*------------)
3      -135.98   16.64  169.25        (------------*------------)
                                -------+---------+---------+---------+--
                                    -120         0       120       240


Group = 2 subtracted from:

Group    Lower  Center   Upper  -------+---------+---------+---------+--
3      -198.94  -46.32  106.29  (------------*------------)
                                -------+---------+---------+---------+--
                                    -120         0       120       240
```

Results for: subjectmeans(Task = T1)

One-way ANOVA: AverageMovement versus Group

```
Source  DF      SS     MS     F      P
Group    2   34796  17398  1.39  0.287
Error   12  150279  12523
Total   14  185075

S = 111.9   R-Sq = 18.80%   R-Sq(adj) = 5.27%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N   Mean  StDev  -------+---------+---------+---------+--
1      5  848.8   95.0            (----------*----------)
2      5  824.7  156.3          (---------*----------)
3      5  736.7   64.3  (----------*----------)
                        -------+---------+---------+---------+--
                             700       800       900      1000

Pooled StDev = 111.9


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 97.94%


Group = 1 subtracted from:

Group   Lower  Center  Upper     +---------+---------+---------+---------
2      -212.8   -24.1  164.6           (-----------*------------)
3      -300.7  -112.1   76.6     (------------*-----------)
                                 +---------+---------+---------+---------
                              -300      -150         0       150


Group = 2 subtracted from:

Group   Lower  Center  Upper     +---------+---------+---------+---------
3      -276.7   -88.0  100.7       (-----------*------------)
                                 +---------+---------+---------+---------
                              -300      -150         0       150
```

Results for: subjectmeans(Task = T2)

One-way ANOVA: AverageReaction versus Group

```
Source  DF      SS    MS     F      P
Group    2   11889  5945  0.61  0.558
Error   12  116343  9695
Total   14  128233

S = 98.46   R-Sq = 9.27%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ---+---------+---------+---------+------
1      5  420.90  154.05           (-------------*-------------)
2      5  386.90   67.79       (------------*-------------)
3      5  351.94   27.52  (------------*-------------)
                          ---+---------+---------+---------+------
                           280       350       420       490

Pooled StDev = 98.46


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 97.94%


Group = 1 subtracted from:

Group    Lower  Center   Upper     +---------+---------+---------+---------
2      -200.01  -34.00  132.01        (-------------*-------------)
3      -234.97  -68.96   97.05     (-------------*-------------)
                                   +---------+---------+---------+---------
                                -240      -120         0       120


Group = 2 subtracted from:

Group    Lower  Center   Upper     +---------+---------+---------+---------
3      -200.97  -34.96  131.05        (-------------*-------------)
                                   +---------+---------+---------+---------
                                -240      -120         0       120
```

Results for: subjectmeans(Task = T2)

One-way ANOVA: AverageMovement versus Group

```
Source  DF      SS     MS     F      P
Group    2   30842  15421  1.91  0.191
Error   12   97140   8095
Total   14  127982

S = 89.97   R-Sq = 24.10%   R-Sq(adj) = 11.45%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  --+---------+---------+---------+-------
1      5  825.22  103.96                (----------*----------)
2      5  782.58   69.96           (----------*----------)
3      5  715.08   92.64  (----------*----------)
                          --+---------+---------+---------+-------
                          640       720       800       880

Pooled StDev = 89.97


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 97.94%


Group = 1 subtracted from:

Group    Lower   Center   Upper  -------+---------+---------+---------+--
2      -194.33   -42.64  109.05      (---------*---------)
3      -261.83  -110.14   41.55  (---------*---------)
                                 -------+---------+---------+---------+--
                                     -150         0       150       300


Group = 2 subtracted from:

Group    Lower  Center  Upper  -------+---------+---------+---------+--
3      -219.19  -67.50  84.19    (---------*----------)
                               -------+---------+---------+---------+--
                                   -150         0       150       300
```