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Skill Acquisition and the Influence of Attentional Focus and Practice

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SKILL ACQUISITION AND THE INFLUENCE OF ATTENTIONAL FOCUS AND PRACTICE

By

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A THESIS

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Definitions

Blocked Practice: Practice that includes a decrease of interference between trials. For example, when learning three different tasks, individuals would practice A-A-A, B-B-B, C-C-C, so that the task is repeated over again before moving on to the next task.

Contextual Interference Effect: The contextual interference effect demonstrates that for groups practicing in a random practice condition, there will be a slower rate of learning during the acquisition process, however will demonstrate increased retention (permanent learning) scores compared to a blocked practice.

External Focus: Individuals focusing externally means the focus is on the outcome of the skill movement, or something in the environment while performing a task. An example includes focusing on the ball during a baseball swing.

Extraneous Focus: Distraction from a tone that directs attention away from skill movement.

Internal Focus: Individuals focusing internally means the focus is on the skill movement, or something the body is doing while performing a task. An example includes focusing on the hands during a baseball swing.

Random Practice: Practice that includes an increase of interference between trials. For example, when learning three different tasks, individuals would practice A-B-C-B-C-A-C-B, so that there is no clear pattern recognized for each trial.

Skill-focus: Distraction from a tone that directs attention to skill movement.

Abstract

Attentional focus and practice schedules are important components in learning a new skill. For attention this includes focusing inward or outward, for practice this includes interference between tasks. Little is known about how the two interact. Four groups; blocked/extraneous (BE); blocked/skill-focused (BS); random/extraneous (RE); and random/skill-focused (RS), practiced 100 trials of golf putting and 64 trials of a key-pressing task in addition to responding to a random tone distracting attention towards or away from skill movement. Participants performed immediate and delayed retention tests. Results demonstrated the BE group had decreased RTE scores compared to the BS group. Immediate retention demonstrated superior scores for blocked practice. Delayed retention demonstrated superior CEVE scores for extraneous focus. For golf putting, both attention conditions with blocked practice learned faster compared to random groups. Posttest scores demonstrated the random and skill focused group to improve in all putting conditions.

Introduction

Learning a new skill is a process that incorporates many variables that aide to reaching an expert level (Fitts & Posner, 1967). Through this learning process, progressions of different phases are achieved in order to become fluent at a desired skill. This can apply to various domains such as sport, rehabilitation, motor learning, and education. Individual characteristics and learning styles, in addition to environmental factors influence how skills are learned. It is the job of the coach/mentor/teacher to ensure a proper learning progression is accessible in order to advance through each phase of skill acquisition so that optimal performance is attained.

Fitts and Posner (1967) describe skill acquisition in three stages. The cognitive stage includes a novice attending to a skill in a step by step fashion, focusing internally on body movements, and freezing degrees of freedom until the skill can be executed. In the associative stage, the novice becomes progressively better at the skill, the amount of feedback decreases, and there is less attention on body movements during skill execution. When the autonomous stage has been reached, the skill becomes automatic and a leaner is able to use proceduralized knowledge in order to execute the skill. Many components go into learning in order to reach the autonomous stage, including available feedback to the learner (Salmoni et. al., 1984), intrinsic or extrinsic motivation (Locke & Latham, 1985), how a learner is focusing attention (G. Wulf, Hoss, & Prinz, 1998), and the order and structure of practice (J. B. Shea & Morgan, 1979). The latter will be the focus of this paper.

When organizing or structuring the learning process of a motor skill, practice can be implemented in many ways; distributed/massed, part/whole, varied/constant, and blocked/random. It is important to clarify each practice condition in order to gain a better understanding of how each play a role in learning a skill. Distributed and massed practice deals with temporal spacing of the practice and rest sessions. Increasing the space of time between sessions is termed distributed. An example would be practicing for one hour over the course of several days. Decreasing the spacing between sessions is termed massed practice and shorter rest periods are given between practice conditions (Donovan & Radosevich, 1999). An example of this would be practicing for many hours over the course of a few days. Part and whole practice deals with either practicing a skill by breaking down components in to sub skills or practicing the entire skill as a whole. Variability of practice deals with learning a single skill of the same generalized motor program, and being able to generalize the same skill to novel tasks (Schmidt, 1975). For example, when learning an overhand baseball throw, the general motor program is the hip rotation, stepping, and arm action. Learning the skill of throwing the ball overhand to a target at different distances, then being able to apply the same generalized motor program for performing an underhand pass, is variability of practice. Blocked and random practice are very similar to variability of practice, however blocked and random practice focuses on different tasks, and usually these tasks involve the use of different general motor programs . For example, when practicing soccer, an individual would learn to shoot, dribble, and pass as oppose to just shooting. Though variability of practice and random and blocked practice sound similar, it is important to keep in mind the difference of practicing one task (variability of practice) or multiple tasks (blocked or random).

PRACTICE

Early work suggested that increasing the amount of interference between trials during the learning process would decrease performance during practice, yet demonstrate greater learning when given a retention test (Battig, 1972). This is called the contextual interference effect, and is observed when the high interference implemented during practice demonstrates a decrease in performance but increase in retention (or learning) of the skill. The amount of interference can be high or low, and is dependent upon the structure of the practice that occurs from trial to trial when learning a new skill. When interference is high, this is termed random practice and signifies multiple tasks being learned in one practice setting. When interference is low, only one task is learned in a practice setting, or repeated over a certain amount of trials before practicing the next task. This is termed blocked practice. For example, when learning to throw a baseball, assume the learner to practice three different throws; overhand, underhand, and a side throw. If a learner was practicing in a blocked order, the overhand throw would be practiced a certain amount of trials before moving on to the underhand and side throw. If a learner was practicing in a random order, all three baseball throws would be performed throughout the practice session. The contextual interference effect is observed when those who practice in a random order demonstrate inferior performance during the learning phase compared to blocked practice, but superior performance when given a retention test. Those who practice in a blocked order demonstrate superior performance during practice, yet inferior performance when given a retention test. Battig (1972) was the first to observe this in the verbal learning domain, and the rationale behind this theory was that a learner practicing in a random order was forced to keep items in working memory from trial to trial, and the end result was an increase in learning (Battig, 1979).

Shea and Morgan (1979) were the first to investigate contextual interference in the motor learning domain. The purpose of the study was to compare random and blocked practice schedules using a motor task during the learning phase (e.g., during skill acquisition), and how the learner retains the information (e.g., on a retention test). The motor skill was a multi-joint arm movement task, and the task included responding to a stimulus light, pushing a start button, picking up a tennis ball, and knocking down wooden barriers in a specific movement patterns. While the subject performed the movement task, four timers were set up to record 1) the movement time from the onset of the stimulus light to when the subject released the start button, 2) the movement time from the release of the start button to the grasping of the tennis ball, 3) the movement time from grasping the tennis ball and knocking down the first barrier, and 4) the movement time for the entire task. There were three movement patterns to learn, and three stimulus colors corresponded to each movement pattern (e.g., 'blue' corresponds to movement pattern 1). Fifty four acquisition trials were administered, and subjects practicing in a blocked order completed 18 trials of movement pattern 1 before moving on to movement pattern 2, and 18 trials of movement pattern 2 before moving on to movement pattern 3. Subjects practicing in a random order practiced all 3 movement patterns for 54 trials in a random order, with the exception being that no clear pattern occurred consecutively (Shea & Morgan, 1979). After the 54 trials of practice, half the subjects were given a retention test of 18 trials, or 6 of each movement pattern, 10 minutes later. The other half of subjects were given the same retention test 10 days later. The retention test included subjects performing in either a random or blocked condition. Reaction time and movement time were analyzed. Reaction time included the time in seconds between the onset of stimulus light and release of the start button, while the movement time was the time in seconds between the release of the start button and termination of the entire task (Shea & Morgan, 1979).

Results demonstrated a learning advantage for the blocked group during the early trials of the practice phase, however there was not a clear improvement over the entire skill acquisition period. The random group demonstrated a decrease in the total time during the early phases of learning. On the last trial block, there was little difference for total time between the blocked and random group. On the retention test, participants who practiced in a blocked condition and performed a random retention test demonstrated inferior performance compared to the other three groups in both the 10 minute and 10 day retention test. Learners practicing in a random condition with a blocked retention test demonstrated superior performance compared to the other three groups in both the 10 minute and 10 day retention test. Therefore, benefits derived from practicing in a blocked practice condition demonstrated improvement during skill acquisition, however inferior performance on a retention test. On the 10 minute retention test, subjects who practiced in a random order with both a blocked and random retention test demonstrated superior performance compared to those practicing in a blocked condition. Therefore, high interference hindered skill acquisition but resulted in improved learning of the multi-joint arm movement task for immediate retention.

An argument was proposed against the methodology used for the contextual interference effect and was investigated by Lee and Magill (1983). The task used by Shea and Moran (1979) required learners to respond to a stimulus light corresponding to a movement pattern before knocking down the appropriate sequence of barriers. The problem with learners who practiced in a random condition was the absence of initial cueing on what task they would be doing beforehand, compared to learners in the blocked practice condition who always knew what movement pattern came next. Therefore, the argument proposed stated the reason for contextual interference effect was a choice-reaction paradigm (Lee & Magill, 1983). In other words, for those practicing in the random condition, when the stimulus light was illuminated a choice had to be made regarding what movement pattern to complete. In the blocked practice condition, no choice had to be made because they already knew what movement pattern to perform. Lee and Magill (1983) manipulated the study by Shea and Morgan (1979) so that a cueing factor was included. The two groups (random and blocked) used in Shea and Morgan's study were replicated and an additional two groups were included. The manipulation included adding a cue before the onset of the stimulus light. The four groups were cued-blocked versus un-cued random, and cued-random versus un-cued blocked (Lee & Magill, 1983). By adding the cueing factor before the onset of the stimulus light, this would resolve the issue of whether or not the contextual interference effect is instigated by choice reaction.

The cued groups received a warning light followed by a stimulus light that were of the same color, indicating which movement pattern to perform, while the un-cued groups received a warning light that was white and the stimulus light indicating which movement pattern to complete. The white light represented the un-cueing factor so that the learner had to respond to the stimulus light as oppose to receiving a warning light for which movement pattern to complete. The procedure was identical to that of Shea and Morgan (1979) in the fact that each group received 54 trials during practice, or 18 trials for movement pattern. Participants were given a four minute interpolated phase that consisted of completing the Stroop task. Because of the cognitive demands of performing the Stoop task, this prevented participants from rehearsing the movement patterns learned during the practice phase. Upon completion of the Stroop task, a retention test was given.

Movement time and reaction time were measured for each of the four groups. Results indicated that during skill acquisition the un-cued random group reaction time was significantly longer than the other three groups. For movement time, the cued groups performed faster than the un-cued group during the practice phase. However, for choice reaction time and cued conditions, the contextual interference effect was not demonstrated. In retention conditions, although there was an effect for reaction time in the fact that choice reaction time was slower during acquisition, no differences were observed between blocked and random groups on the retention test. This indicated that reaction time affected performance during skill acquisition but not retention (Lee & Magill, 1983). The importance of this study was not only replicating the findings of Shea and Morgan, but also clarified if the contextual interference effect was due to choice reaction. Therefore, random practice conditions contributed to the learning of the skill.

The present study encouraged future studies to measure reaction and movement time as the dependent variables.

It was hypothesized the reason why random practice resulted in better retention scores was because there was an elaborating mechanism occurring for the learner (Shea & Morgan, 1979; Shea & Zimny, 1983). The elaboration hypothesis states that the increased involvement of the working memory for random practice conditions leads to an in-depth information processing strategy. Compared to blocked practice, the learner is repeating the same task so no comparison of actual performance between trials can be made. The second hypothesis of the contextual interference effect was inspired by previous work done by Jacoby (1978). Applying it to the motor domain, Lee and Magill (1985) proposed that a reconstruction effect was occurring during learning of a task. For random practice, a person becomes more engaged in learning by having to continuously forget and remember the demands of the task during the initial stages of learning (Lee & Magill, 1985). This creates an opportunity for the learner to generate an action plan for every single trial, whereas in blocked conditions, cognitive demands are not as high. Therefore, requirements for the task are constantly in working memory and forgetting does not occur (Lee & Magill, 1985). Both the elaboration theory and reconstruction hypothesis suggest that random practice promotes higher amounts of processing before each trial, therefore increasing the attainable knowledge of the task on a retention test. The importance of these hypotheses would encourage researchers to continue to apply the contextual interference effect in other domains, or address concerns in the methodology used. For example, the elaboration hypothesis and reconstruction theory is related to information held in working memory from trial to trial. A component of the reconstruction hypothesis states that it is the individual's knowledge of results or action plan that is forgotten before every trial (Lee & Magill, 1985, p. 19). However, providing knowledge of results so that the learner can execute an appropriate action plan had not been implemented in previous studies concerning contextual interference.

Shea and Wright (1991) conducted an experiment to better address reconstruction mechanisms by manipulating previous studies attempting to isolate the level of forgetting, and in addition added knowledge of results so that this would aide in reconstruction of an action plan before every trial. Replicating the methods used by Shea and Morgan (1979), the participant's tasks included releasing the start button, and with the onset of the stimulus light, grasp the tennis ball and knock down a sequence of wooden barriers in a movement pattern. There were three different movement patterns the participant could knock down with the tennis ball (e.g., left middle-right middle-left rear-right front; right front-left rear-right-rear-right middle; or left middle-right rear-left rear-right front). The added manipulation in this study included the interpolated activity the participants did after performing the first trial, but before performing the retention test. The acquisition trial included the participants knocking down only one movement pattern, based on the task diagram presented (that corresponded to which movement pattern to knock down), in addition to receiving knowledge of results with respect to total movement time upon termination of the trial (since the object was to complete the task as quickly as possible). After the acquisition trial, participants performed an interpolated task. Four groups performed either the same task, a similar task, a dissimilar task, or no task before moving on to the second acquisition trial.

The same task group was given an additional task of knocking down the exact movement pattern performed on the first acquisition trial. The similar group performed the same task but a different movement pattern than was performed on the first acquisition trial. The dissimilar group attempted to solve a jigsaw puzzle that encouraged forgetting of the action plan for the acquisition trial. The no task group did nothing for the interpolated activity. After the interpolated activity, an acquisition test was given that directly assessed the action plan generated in working memory by the participant. This test was identical to the first acquisition trial, however participants did not receive the task diagram and knowledge of results were not provided. Immediately following the acquisition test, a second acquisition trial (which was identical to trial 1) was performed and knowledge of results was provided to give the participant an opportunity to reconstruct an action plan. Following a 2-minute retention interval, two retention tests were given. For the first retention test, the procedures were identical to the first acquisition trial and first acquisition test; however knowledge of results were not provided. In the second retention test (which was the same as the first retention test), knowledge of results were provided. The purpose of the first acquisition trial was to observe the cognitive processes for generating an initial action plan, while trial two attempted to address the reconstruction processes of the action plan after the interpolated activity.

Results demonstrated that the similar and dissimilar groups did not differ with respect to the percent of correctly performed tasks. However, the percent of correctly performed tasks was lower compared to the same and no task groups. The percent of correctly performed tasks were not different between the same and no task groups. What these findings suggest is that the similar and dissimilar groups forgot the action plan as a result of the interpolated activity compared to the same and no task groups. Therefore, the similar and dissimilar groups had to engage in more reconstruction for performing the second trial (Shea & Wright, 1991). For retention test 1, the similar task, no task, and same task groups correctly performed more tasks than the dissimilar task. Reaction time and movement time was slower for the dissimilar and similar task compared to the same task and no task groups, though this was not significant. This study intended to further investigate the reconstruction hypothesis by manipulating the amount of forgetting in a trial. Shea and Wright proposed that forgetting is not necessarily the only factor that is beneficial for improved learning. Those who practiced the similar task performed better than those who practiced the dissimilar task; therefore reconstruction did promote better learning. The results from retention test two as a measure of response execution demonstrated that the similar task group generated more detailing of task parameters during reconstruction (Shea &Wright, 1991). The same and no task groups were intended to simulate low interference, while the dissimilar and similar tasks were intended to simulate high interference. The authors suggested that the dissimilar group and similar groups should have had superior performance on retention tests if forgetting is a factor that plays in to retaining the information. However one detrimental part of this study includes the number of subjects analyzed in each group (dissimilar task = 4; similar task = 6; same task = 12; no task = 10).

In addition to the mechanisms responsible for reconstructing an action plan, curiosity about the spacing of trials and retention manipulations were observed. The spacing effect was originally proposed by Lee and Magill (1985), and Meeuwsen and Magill (1991) performed a study addressing the amount of time between trials, or if there is a spacing effect happening that can explain contextual interference. The importance of this experiment was the fact that this study did not directly measure the contextual interference effect, but the spacing of trials to explain performance in retention. For example, if a learner is practicing in a blocked order, the learner might practice task A, B, and then C with 6 seconds in between each trial, or the learner might practice task A, B, and C with 20 seconds in between each trial. When the learner is given a retention test, does this spacing between tasks affect the performance on a retention test?

The purpose of Experiment 1 was to examine if a random practice condition is necessary for spacing of repetitions effect. Therefore, a random practice condition was compared to an immediate repetition, 20 second empty interval, and a two related activity interval (explanation of these groups will be provided below). The apparatus was a board that consisted of 5 stimulus response buttons. The task was to push these switches in a specific movement pattern within a certain amount of time. A computer was used that controlled the duration of the stimulus light, knowledge of results, and collection of all other data. The goal task movement times included moving from switch 1 to 2 in 900 ms, and 2 to 3 in 1200ms. The immediate repetition group performed all 30 acquisition trials of the task goal with a 6-second interval. The 20-second empty condition included performing all 30 acquisition trials of the goal task only, and each trial was separated by 20-second intervals. The two related activity condition included subjects having to learn two tasks between each trial of performing the task goal. The random group performed the goal task and two related tasks in a random order during acquisition. Knowledge of results was provided after trials. A five-minute and one-week retention test was given on the goal task only.

Results revealed that during practice, subjects in the empty interval condition performed better than any other group. The immediate repetition group and empty condition group had superior performance compared to the two related activity and random group. Results from this study are not consistent with the spacing effect and contextual interference posed by Lee and Magill (1985). If there was a spacing effect to help explain contextual interference, than the random group and empty condition of the 20 second interval during each trial should have resulted in similar retention benefits. However, one problem with the experiment could have been the difficulty of the task. Therefore, this was measured in the second experiment. The second experiment was similar to that of Experiment 1, however only one movement time was performed as opposed to two. Results demonstrated that task difficulty played a role, however the random group and empty condition group still did not yield the random benefits that were expected to be observed, demonstrating a clear difference between the spacing of repetitions and contextual interference paradigm. The importance of the third experiment supports retroactive interference during acquisition, which states that by practicing in a blocked practice condition, poor retention is a result of another interpolated activity between the original learning and retention test (Underwood, 1945). In other words, if a learner is practicing in a blocked condition, everything about task A will be learned before practicing task B. If a random retention test is given for both task A and B, the learner retrieves information from working memory on what they learned when performing task A. This retroactive inhibition could possibly be a reason why the contextual interference effect was happening.

Del Rey (1994) implemented a study to further investigate this. The task was similar to the arm-movement task described by Shea and Morgan (1979). However, instead of knocking down a sequence of wooden barriers, participants were to push keys in response to a stimulus light. Three movement patterns corresponded to a specific color (red, blue, white). The retention test included only performing the movement pattern corresponding to the red color. In addition, a transfer test that consisted of a different movement pattern (assigned the color green) was given to each group. Since participants were given a retention test that consisted of the red movement pattern only, the manipulation of the four groups included at what point during the practice phase they performed the red movement pattern. A control group performed 18 red movement patterns only. A blocked-without group performed 18 blue, 18 white, and 18 red movement patterns so that the red movement patterns were performed right before the retention test of red movement patterns only. A blocked-18 group performed 18 white, 18 red, and 18 blue movement patterns, so that red movement patterns were performed 18 trials before given the retention test. And the blocked-36 group performed 18 red, 18 blue, and 18 white movement patterns, so that 36 trials were performed before given the retention test of red movement patterns only. The last group was random, and performed 54 trials of each color in a random order. After 10 minutes, a retention test of 5 red movement patterns were performed only, in addition to a transfer test of 5 green movement patterns. Results demonstrated the contextual interference effect in that during acquisition, the random group had longer reaction times compared to all three blocked groups. The random group also demonstrated significant improvement from the early stage of skill acquisition to the later stages of skill acquisition. For retention and transfer tests, subjects in the blocked-without (who performed 18 red movement patterns before given the retention test ten minutes later), random group, and control group (who only performed 18 red movement patterns) had shorter reaction time than the blocked-18 and blocked-36 group, but only for the first and second trial. Movement time was not significantly different between all groups in both retention and transfer trials (Del Rey et. al., 1994).

To this point, evidence has been observed for random practice to promote better learning and transfer of a skill during retention and transfer tests when using an arm movement segment task. It has even generalized to other domains such as logic operations (Carlson & Yaure, 1990), foreign language vocabulary (Schneider, Healy, & Bourne, 2002), and handwriting (Ste-Marie, Clark, Findlay, & Latimer, 2004). For example, Ste-Marie et al. (2004) tested contextual interference in handwriting by drawing three replicated symbols taken from the International Phonetic Alphabet. For the blocked group subjects performed 24 trials of one symbol before moving on to the next, and for the random group the trials were randomized so that an equal number was in each block of the three trials. After a 30-minute interpolated phase, a retention test was given in either a blocked or random condition. Therefore, the four acquisition and retention groups were: blocked-blocked, random-random, blocked-random, random-blocked. Results indicated blocked scores during acquisition were superior to that of random scores. Both groups who performed trials in a random order performed better than blocked during acquisition (Ste-Marie, et al., 2004). However, when learning a new skill it usually does not happen within an hour setting. These studies have displayed evidence for random practice after learning of a skill, but how does it affect practice over a period of time?

Using a real-world example and testing it in a lab setting, Del Rey assessed recreational subjects using an anticipation task to measure practice conditions on retention and transfer when learning a new skill, instead of assuming expertise with already developed temporal processing (Del Rey, 1989). Compared to previous studies that learned a skill and performed a retention test the same day, untrained novice subjects underwent two practice days per week for four weeks (Del Rey, 1989). The practice phase and initial scores obtained for each participant was collected from the Basin Anticipation Timing task. The task included participants having to respond to a moving light traveling down a runway at a certain speed. Once the light reached the end of the runway, participants had to respond by pushing a button that would terminate the light. The initial test phase consisted of two groups that were either in a random practice condition or blocked practice condition. Each group was presented with 64 acquisition trials. The blocked group practiced 16 trials of the same speed (either 5, 7, 11 or 13mph) before moving on to the next speed, while the random group practiced all four speeds in a random order. Half of the subjects then performed a retention test of each of the same speeds in a random or blocked condition on the same day.

After the retention test, training consisted of practicing twice a week for four weeks on tennis skills, which directly correlates with anticipation of spatial and temporal movements of the flight and location characteristics of the tennis ball (Del Rey, 1989). After training, the same retention test was given after the four weeks of practice, in addition to 12 transfer trials of either 6 or 12 mph. Knowledge of results were presented after each trial. Results demonstrated that during practice of the tennis skills, the random group demonstrated increased errors, as predicted by the contextual interference effect. Though there was not an interaction, the random group experienced less errors than the blocked group for both retention and transfer conditions. Subjects who were in the blocked group during practice performed worse when given a random retention test compared to subjects who practiced in the random condition. The best practice conditions were subjects who practiced in the random condition with a random retention test. One flaw in this study is that during the four weeks of practice, both random and blocked groups had identical practice conditions.

Del Rey (1989) did not directly measure the task of interest using random and blocked practice, which was the anticipation and response to a light traveling down a runway. Instead, participants practiced anticipation timing tasks in tennis. Goode and Magill (1986) specifically measured the task of interest in addition to practicing the same task over the course of several weeks. This was the first study that observed contextual interference in an applied setting of the sport domain. Using badminton as the task, subjects were required to learn three different serves; short, long, and drive. The subject was instructed to serve to a designated area on the opposite side of the court. Points were awarded based on where the shuttle landed in a specific spot on the opposite side of the court. More points were awarded if the shuttle landed in the target area. If the shuttle landed outside the area, subjects received a 0 (Goode & Magill, 1986). The groups assigned were random, blocked, or serial, and practiced a total of 324 trials, or 108 trials of each of the three serves. Practice occurred for three days a week for three weeks. On each day, 3 blocks of 12 trials were practiced for 36 trials total. On each of these days, the blocked group practiced only one serve for all 36 trials. The random group performed all three serves randomly for the entire 36 trials every day, with the exception being that all three serves were practiced with no single serve being practiced more than two times in a sequence (e.g., A-C-D, B,A,C). The serial group was similar to the random group, the difference being subjects in the serial group performed the long, short, and drive serves in a sequence for all 36 trials (A-B-C, A-B-C). Knowledge of results was provided about individual scores on each trial. After the last day of the practice phase a retention and transfer test was given and knowledge of results were not provided. The retention test included performing all three serves in a random order. For the transfer test, subjects performed all three serves in a random order from the opposite side of the court than what was originally practiced during acquisition. Results demonstrated no interactions for the random and blocked practice conditions on the three different serves during acquisition, and all three groups learned at the same rate. However, for retention and transfer tests, random practiced demonstrated better learning for the short serve only.

Wrisberg and Liu (1991) used the same badminton task with the objective of studying the contextual interference effect in a natural environment as oppose to a strict, laboratory setting. Subjects were recruited from a standard college badminton class. The two tasks consisted of the long and short serve. Similar to procedures done by Goode and Magill (1986), points were awarded based on where the shuttle landed on the opposite side of the court, and the scoring zones were 55, 75, 95, and 115 cm from the center line. The study was held during class periods on three different days for 50 minutes, and after a pretest of the long and short serve, subjects performed 6 trials of each serve in order to establish two groups who demonstrated similar results on performance of the skill. After groups were established, both groups began a practice phase that occurred over five different class periods. Each class period, groups performed 18 trials, or 9 of each the long and short serve. Subjects in the random group performed all 18 trials of the long serve and short serve randomly, while the blocked group performed 9 trials of the short serve before practicing 9 trials of the long serve. After the five days of practice, subjects performed the test phase that included a retention and transfer test. The retention test was 12 trials total or 6 trials of each of the long and short serve. The transfer test was performing the same amount of trials; however participants served from the opposite side of the court to what was practiced during the initial practice phase. Results indicated that on day four and five during acquisition, the blocked group was superior to that of the random group. For retention, the random group performed better than the blocked group on the short serve only. A possible reason for this is that the short serve requires less force and more precise measurement for hitting the shuttle. In the transfer condition, the random group was superior to that of the blocked group for both the long and short serve.

Continuing with the investigation of the contextual interference effect in a natural environment as oppose to a strict laboratory setting, Boyce and Del Rey (1990) were interested in novices who had no experience performing a rifle shooting task from different locations. Another interest of this study was to see how participants who practiced in a random setting performed when given a blocked retention test. Instructions on proper gun handling were given in addition to a practice trial of shooting the rifle. Following instructions, subjects performed a pre-test. The next five days included the acquisition trials, which totaled 20 shots performed over four days, or 5 shots per day. There were four different target locations, and the blocked group was instructed to shoot at one target location per day. The random group shot at all target locations on each day of practice. Five immediate retention trials were performed 15 minutes after the last acquisition trial on the fourth day. Subjects also performed a delayed retention test seven days later. For the retention test, the target locations were presented in a blocked condition, the same as the blocked group performed during acquisition. In addition to the second retention test given the seventh day, a transfer test was given on a different shooting task. Results demonstrated that during acquisition, subjects who practiced in the random practice condition had inferior scores compared to the blocked practice condition. In addition, no interactions were observed for retention and acquisition trials. However, for transfer conditions those who practiced in a random practice condition had superior performance than those practicing in a blocked practice condition (Boyce & Del Rey, 1990).

The contextual interference effect has been shown to generalize to other sports. Bortoli et al. (1992) studied novice volleyball players. The groups were split in the typical blocked and random practice conditions. However, additional groups were added to manipulate the amount of interference given to participants. These two additional groups were serial, and serial with very high interference. The task included practicing three different volleyball skills; the bump, volley, and underhand serve, to a specific target location on the opposite side of the court. Lessons were given once a week for two months (Bortoli, Robazza, Durigon, & Carra, 1992). Scores were given to each participant based on where ball landed on the opposite side of the court in the target area. The blocked group practiced one skill per session, while the random group practiced all three skills in a random order for each session. The two additional groups, serial and serial with very high interference, practiced each volleyball skill in a sequential order (A-B-C, A-B-C). The difference for the serial and serial with very high interference was that the serial group practiced one skill for 6 times before moving on to the next, while the serial with very high interference only repeated the skill twice before moving on to the next one. A retention test included performing 6 trials of the bump, volley, and serve, to a specific target on the opposite side of the net. The transfer test included moving each target either 1 meter closer or further from the original location. Results demonstrated that during the practice phase there were no significant differences between all four groups, and all groups had similar performance when learning the skills. However, the random and serial group demonstrated superior performance compared to the blocked and serial group with high contextual interference on the transfer test. The long transfer test, which was considered to be most difficult, demonstrated random and serial practice conditions were more beneficial, suggesting in a more elaborate cognitive processes for learning the task (Bortoli, et al., 1992).

Hall, Domingues, and Cavazos (1994) demonstrated a very strong contextual interference effect in the sport domain using expert baseball players as subjects. The baseball task was to hit 45 fastballs, 45 curveballs, and 45 change ups. Baseball players were split in to three groups that included a control group, random group, and blocked group. After a two day pretest, a blocked group hit 15 pitches of the same pitch before moving on to the next one. The random group hit each pitch in a random order, so that no pitch occurred more than twice in the session. The control group had no specific pattern of hitting. In the testing phase, retention tests were given in either a random or blocked practice condition. Results demonstrated that during practice, the blocked group had a higher mean for number of hits compared to the random and control group, though the interaction was not significant. Results from a retention test demonstrated the random group performed better than the blocked group, while the blocked group performed better than the control group (Hall, Domingues, & Cavazos, 1994).

Hall et al. (1994) suggested the contextual interference effect to be very robust in applied settings. However there have been many studies that have demonstrated mixed results for the contextual interference effect in applied settings. For example, Hebert et al. (1996) had subjects learn a forehand and backhand stroke in tennis, comparing low skilled and high skilled tennis players. Subjective measures and pre-test scores were obtained that would separate students in either a high or low skilled group. The first three days students were taught the fundamentals of the forehand and backhand hits. The pre-test happened on the fourth day of practice and trials were given in a blocked order (10 consecutive trials of the forehand then backhand stroke). The task was to hit the ball between the net and suspended cord on the opposite side of the court (Hebert, et al., 1996). Students were assigned to either a blocked or random practice condition. On the ninth day of practice, two post-tests were given, in the same blocked condition as was given in the pre-test phase, in addition to 20 strokes performed in an alternating fashion. Results demonstrated the higher skilled subjects to have superior performance compared to the low skilled group. In addition, low skilled students who practiced in a blocked practice condition scored higher than those who practiced on the alternating schedule on the blocked and random retention test. This study demonstrates the benefits of low skilled (novices) individuals performing in a blocked condition in an applied setting, to perform better on a retention test (Hebert et. al., 1996). This relates to Fitts and Posner's (1967) model of skill acquisition in the fact that a novice needs to get a feel of the movement before becoming proficient at the skill.

Brady (1997) attempted to demonstrate the contextual interference effect in a more applied setting. Using a golf task, subjects practiced the drive, middle distance iron, pitch, and chip shots as fundamental skills learned by novice golfers. Performance was measured by the final score obtained from 18 holes of golf. Before subjects played the 18 holes of golf, they practiced at a driving range and performed each shot in either a blocked or random practice setting. This included 15 trials of the same shot before practicing a different shot for the blocked group, while the random group performed 15 shots in a random order. After this pretest, subjects played 18 holes of golf. The score cards were collected and measured for results, and no differences were observed between the random and blocked groups for the total number of shots to complete 18 holes. One detrimental part of this study was the few number of trials used to observe the contextual interference effect. In addition, learning 4 skills might have created too much interference (Brady, 1997).

Meira (2002) had subjects perform a dart throwing task to a specific target using different grip patterns. To this point, because the contextual interference effect displayed vague differences during transfer trials, in that some studies demonstrated random practice to be beneficial for transfer while other studies had not, another purpose of the study was to observe if the contextual interference effect would be stronger if there were more trials on the transfer test. During practice, the task included throwing a dart using different hand grips to a target from different locations. Subjects performed 80 trials in either a blocked or random practice condition. Subjects who practiced in the blocked condition performed one throw using one grip at one location for a certain amount of trials before moving on to the next. Subjects in the random group performed each throw from each location in a random order for the entire 80 trials. A transfer test using a different grip (or type of throw) included 40 trials that were given ten minutes after the last acquisition trial. Results demonstrated that on the transfer test, the random group had superior performance from the first block of trials to the last block of trials. The blocked group had superior performance on the first block of trials and plateaued in performance for the final trial blocks, however there were no differences between the groups (Meira & Tani, 2001).

Jones and French (2007) used volleyball tasks practicing the underhand serve, forearm pass, and overhead set. The object of the task was to hit the ball to a specific target on the opposite side of the court. Points were awarded based on where the ball landed. The practice phase lasted 9 days, and each subject practiced thirty trials per day. The blocked group practiced one skill per day for the duration of practice over the 9 days. For example; on day 1, 4, and 7 subjects practiced the underhand serve only, while on day 2, 5, and 8, subjects practiced the forearm serve only. The random group practiced all three skills each day during the practice phase. There was also a third group (blocked-random) that practiced all three tasks in one day, however in a blocked practice schedule. For example; subjects practiced 10 trials of the underhand serve, 10 trials of the forearm pass, and then 10 trials of the overhead set, for 30 trials total on each practice day. A retention test was given two days later on the same three skills learned during the practice phase. Results demonstrated that all three groups improved scores during the practice phase; however there were no differences between groups at the end of practice. In addition, no differences were found between groups on the retention phase, indicating an unclear advantage as to what practice condition was optimal for learning.

Though these studies failed to produce the contextual interference effect in an applied domain, an interesting concept proposed states that increasing the amount of interference across practice conditions might be more beneficial as oppose to practicing with either very high interference (random) or very low interference (blocked). For example, Porter (2005) had subjects perform a golf putting task from three different locations to a target. Based on where the ball came to a stop in the target area, points were awarded. Subjects were to complete 81 trials, and the blocked group performed 27 golf putts from one location before moving on to the next, while the random group performed all 81 trials in a random order. The increasing group practiced with increasing interference across practice conditions. For example, the first 27 putts were practiced in a blocked order (or 9 trials from one location were completed before moving on to the next), the next 27 putts were practiced in a sequential order, meaning that subjects putted from location 1, 2, and then 3, in the same order for 27 trials. The last 27 trials were random. Results demonstrated that participants who practiced with increasing interference demonstrated superior performance to that of blocked or random groups during retention conditions. In addition, the contextual interference effect was not demonstrated for high and low interference (Porter & Magill, 2005).

It is important to note that Battig originally stated that during learning, the amount of interference can increase by either increasing the degree of task similarity, or scheduling practice in a random order. Wood and Ging (1991) investigated how task similarity plays a role when practicing in a blocked and random condition using a multi-joint arm movement task similar to Shea and Morgan (1979). Using a stimulus panel and response board, eight targets were presented on the board, along with six different movement patterns, three of which consisted of the same movement pattern (the movement pattern represented the shape of the letter “N”). The same movement patterns represent high task similarity. There were three patterns that had no specific movement pattern, so that there were no predictable movements to the next target on the board (representing low task similarity). There were two groups and two conditions, in addition to a control group. The groups were random and blocked, and both groups practiced the similar task or dissimilar task. Therefore, groups were as follows; blocked/similar, blocked/dissimilar, random/similar, random/dissimilar, and a control group. The blocked and random groups performed either the similar or dissimilar task, totaling 3 movement patterns for each group. Upon receiving a warning buzzer and response stimulus for which movement pattern to perform, subjects depressed the appropriate target switches in order to complete the pattern. 24 acquisition trials were performed for each movement pattern for a total of 72 acquisition trials. The blocked practice group performed 24 trials of one movement pattern before moving on to the next, while the random group performed all 72 trials in a random order. A retention test was given 5 minutes later on twelve trials, or four of each movement pattern. Half the subjects performed trials in a blocked practice condition during acquisition, but randomly on a retention test. The other half of the subjects performed acquisition trials in a random practice condition, but in a blocked practice during retention. After the retention test, a transfer test was given, and the patterns on the board were rotated 90 degrees (so that the “N” was now a “Z” movement pattern, while the other was still random).

Results indicated that during practice, all groups had a faster reaction time during the final trials of acquisition. During the practice phase, the random group had slower reaction times compared to the blocked group, and the groups who performed the high similarity tasks had quicker reaction time than groups who performed the low similarity task. For movement time, those who practiced the high similarity task performed faster than those who practiced the low similarity task. Subjects who practiced in a random condition had slower movement time in the beginning of the practice phase; however at the end of the practice phase subjects in the random group demonstrated faster movement times compared to the blocked group.

Results from the retention test demonstrated that for reaction time, the high similarity group reacted faster than the low similarity group. Subjects who practiced in a random practice condition during acquisition reacted slower than those who practiced in blocked conditions. It was also demonstrated that reaction time was faster during the last block of practice trials compared to the initial trials on the retention test. Subjects who practiced in a blocked practice condition had an increase in reaction time compared to the last few trials during the acquisition phase. Subjects who practiced in a random practice condition during acquisition had an increase in reaction time on retention scores compared to those who practiced in a blocked practice condition. The main interaction from the retention conditions demonstrated that subjects who practiced the low similarity tasks in a blocked practice condition demonstrated larger increases in reaction time than those who practiced in a blocked practice condition on high similarity tasks.

Retention tests also demonstrated that subjects who practiced in a blocked condition during acquisition and had a random retention test reacted slower than those who practiced in a random condition. For task similarity, both the random and blocked practice groups who performed the tasks of low similarity had an increase in reaction time on the retention test. The blocked and random groups who performed the high similarity tasks performed at a faster movement speed compared to those who practiced low similarity tasks. In addition, those who practiced in a random condition had a similar movement speed on the retention test compared to the last few acquisition trials. In conclusion, the high similarity task promoted faster learning during acquisition, and random practice resulted in better learning on retention. The high similarity groups were able to use memory recall for the similar movement patterns in order to complete the next trial. Practicing in a random order with high similarity tasks did not produce faster learning during acquisition trials, but did maintain performance during the retention tests (Wood & Ging, 1991).

Lee, Wulf, and Schmidt (1992) point out a very important hypothesis proposed by Magill and Hall (1990) that studies failed to address in their methods. Studies that did not produce the contextual interference effect have used the same general motor program when learning a task. General motor programs are the same muscles or muscle actions that involve the same motor control mechanisms to carry out a certain task. Magill and Hall (1990) hypothesized that the contextual interference effect would be most supported when using different general motor programs. For example; if an individual practices throwing a baseball, using a same throwing pattern (such as an overhead throw) at different target locations would not produce the contextual interference effect. However, if that individual practices three different throwing patterns (overhead throw, side arm, and underhand), would produce the contextual interference effect (Magill and Hall, 1990). Tasks that use the same general motor program is related to Schmidt's (1975) schema theory suggesting that learning a single skill of the same generalized motor program will aide in helping the learner generalize the same skill to novel conditions. Wood and Ging (1991) manipulated task similarity, however, they did not change the general motor program used for the pattern.

Based on Magill and Hall's review, Lee, Wulf, and Schmidt (1992) proposed that greater interference would occur when both the general motor program and parameter modification would manipulate from trial to trial during practice. For a multi joint arm movement task, the general motor program would be the time from one movement segment to the next, and the parameter modification would be manipulating the total movement time. The apparatus used was a wooden base with four electromagnetic switches. These switches were in the shape of a diamond. The object was to move from the first micro switch (which would be the "home" plate in baseball) to the left, and end at the right switch (which would be "first" base in baseball) in a specific time recorded in milliseconds. The task was to complete each movement segment in a specific amount of time. Movement segment 1 was from microswitch 1 to 2 (or home plate to third base), movement segment 2 was from 2 to 3 (or third base to second base), and movement segment 3 was from 3 to 4 (or second base to first base). Each movement segment had a specific goal movement time. Subjects were split in to four different groups; blocked/same phasing, blocked/different phasing, random/same phasing, random/different phasing. Testing occurred on two consecutive days. Both days included 90 acquisition trials, 12 same phasing transfer trials, 12 different phasing transfer trials, and 12 retention trials. One random and one blocked group practiced in the same phasing condition, which included the three movement variations to have the same relative timing. The other blocked and random groups practiced in a different relative timing condition that included the three movement variations to have different relative timings. For example, the same phasing condition included the three movement tasks to have the timing for each segment to be 150-300-225 milliseconds; 200-400-300 milliseconds; or 250-500-375 milliseconds (meaning the groups had 150 ms to complete segment 1, 300 ms to complete segment 2, and 225 ms to complete segment 3, respectively). This resulted in the proportions staying the same (same-phasing group) at 0.22-0.44-0.33 for each movement task. The different phasing group was similar except the movement time goals of 225-150-300ms; 200-400-300ms; or 500-375-250ms resulted in different proportions for each movement task (0.33-0.22-0.44, 0.22-0.44-0.33; 0.44-0.33-0.22). By having different relative timings (different phasing group), this manipulates the general motor program. Of the 90 total acquisition trials, the random practice condition practiced all 90 trials in a random order, while the blocked group practiced 30 trials of the same movement pattern before proceeding to the next. Knowledge of results was displayed after each trial. The 12 retention trials included the movement time for each segment that both groups performed (200-400-300 ms). The same phasing transfer task included movement times 300-600-450ms, which were the same requirements for the same phasing group, but had the same proportions as the different phasing group (0.22-0.44-0.33). For the different phasing transfer task, the movement time for each segment was 600-300-450 ms, and the timing requirements were different and had not been performed previously (0.44-0.22-0.33) by either group.

Results demonstrated both groups increased their performance over the two days of practice. However, no differences were observed between the blocked and random groups in both same phasing practice and different phasing practice acquisition trials. During retention, the same phasing practice condition demonstrated the random group to have less variable error than the blocked group, however this was not significant. In addition, for the different phasing practice conditions for retention, no significant differences were found. Results were similar in both transfer tasks as well, in the fact that even though both groups improved in performance, there were no significant interactions. Results from this study did not support Lee and Magill's (1985) argument that there should be an increase in contextual interference when the overall duration and relative timing are both different, nor did they support Battig's (1979) original hypothesis that tasks that are highly similar should produce a stronger contextual interference effect. Lee, Wulf, and Schmidt (1992) argue that the nature of the task used in the present experiment, with three different goal movement times, might have been too difficult to see the contextual interference effect.

Wulf and Lee (1993) further tested this by manipulating the overall duration (different parameters) but holding the relative timing constant (same general motor program). The apparatus was similar to the study above, in that the response buttons were arranged in a diamond shape and the task was to hit the buttons in a specific order (home base – third base – second base – first base), with goal movement times for the three movement segments (movement segment 1, home base to third base; movement segment 2, third base to second base; movement segment 3, second base to first base). The goal movement times for each segment were; 200-400-300 ms; 250-500-375 ms; 300-600-450ms. Therefore, all proportions were 0.22-0.44-0.33, however the goal movement times were different. In other words, the overall relative timing was the same (using the same general motor program), however the overall durations were different (different parameters). There were two groups, blocked and random, and both performed 108 trials, or 36 of each movement. The random group received the information in a serial order, meaning each task was executed in the same sequence of (A-B-C-A-B-C), while the blocked groups practiced trials in a blocked order but the order of the trials were counterbalanced (e.g; BCA, ABC, CAB), and practiced all trials of one task before moving on to the other. Knowledge of results was either displayed after every trial or every couple trials. It was hypothesized that by decreasing the amount of feedback, this might expose the contextual interference effect. An immediate and a delayed retention test consisted of 4 trials of each movement task, or 12 trials total. In addition, a transfer was given that included trials having different overall times (350-700-525) but the same proportion. No differences were found between random and blocked groups. During immediate retention, the random group increased their errors from the first to the second retention block, while the blocked group decreased their errors, though both groups were very similar. In conclusion, having different relative timings (different general motor programs) seems to be a prerequisite for producing the contextual interference (Wulf & Lee, 1993).

Lee, Wulf, and Schmidt (1992) manipulated both the same general motor program by having different relative timings, and the overall duration (or parameters), but failed to produce the contextual interference effect, and was argued the task used might have been too difficult to produce the contextual interference effect. Wulf and Lee (1993) kept the relative time the same (the same general motor program) but manipulated the parameters used and decreased the knowledge of results, and also failed to produce the contextual interference effect. Wright (2005) conducted a study that included only two movement times to simplify the task, and had different relative timings (different general motor programs) but kept the overall duration the same (the same parameters). The experiment was conducted using the e-prime software on a numeric keyboard, and the task was to release the '2' key, and then push 6-5 (Wright, Magnuson, & Black, 2005). The overall duration stayed the same, so that the subject had 800 ms to complete both tasks. The two tasks were different in relative timing in the fact that one task required the first movement time from 2 to 6 to be completed in 200 ms, while the second movement time from 6 to 5 required the subject to complete it in 600 ms. This was termed task 25S. The second task, termed 75S, was the opposite in the fact that the first movement time from 2 to 6 was to be completed in 600 ms while the second movement time from 6 to 5 had to be completed in 200 ms. Subjects sat in front of a computer screen, and were always informed on which task was to be completed. Subjects started with their finger on the '2' key, then the task code was displayed (either 25S or 75S) for 4 seconds. After seeing a fixation (++) appear on the screen randomly anywhere between 500-2,000 ms, the task code appeared on the screen (25S or 75S) to which the subject had to complete the key pressing task as accurately as possible (either in 200ms or 600ms). 64 trials were performed of each task code, and subjects in the random group performed all 64 trials in a random order. Subjects in the blocked group performed 32 trials of one task code before moving on to the next. For retention conditions, subjects received a pairing condition that displayed either the relative time and overall duration, or just the overall duration. For example, 25S-25S displayed both the relative time of 200-200 ms, while ?-75S displays only one movement time (600ms) but not the overall duration. Results demonstrated a strong contextual interference effect in that subjects who practiced in a block practice condition during acquisition had superior performance than those who practiced in a random practice condition, however the random practice condition demonstrated superior performance on the retention test. This study supports having different general motor programs (different movement times for each segment) in order to produce the contextual interference effect (Wright, et. al., 2005).

Despite the vast amount of literature on contextual interference, to some degree, reconstruction (e.g., random practice) from trial to trial leads to better retention or learning of the skill. Magill and Hall's hypothesis that by having low task similarity that uses different general motor programs has a stronger advantage producing the contextual interference effect. This effect has been stronger for strict, laboratory settings using discrete multi-joint arm movement tasks compared to natural environments (such as in the sport domain) of continuous tasks. Studies that have investigated the contextual interference effect in a natural setting outside the laboratory have either manipulated the force motor program (Goode & Magill, 1986; Porter & Magill, 2005; Wrisberg & Liu, 1991) or the muscle motor program (Jones & French, 2006), however these studies have not manipulated both the force motor program and muscle motor program. In a meta-analytic study by Brady (2004), 63 studies containing 139 effect sizes for contextual interference were obtained and analyzed. Studies were included in the Meta analysis based on the nature of the research (if it was basic in the laboratory or applied in a natural environment), the amount of contextual interference (high or low interference), the age level of participants (children/adults), and the skill level (expert compared to novices). Using Cohen's *d* as an index, the overall mean effect size for basic or lab oriented research was 0.57, while applied (in a sport setting) was 0.19. For adults, it was 0.50 and for children it was 0.09. Finally, for retention the overall mean effect size was 0.40, while transfer was 0.31. Cohen (1988) reports 0.50 as moderately seen differences, therefore suggesting vague support for the contextual interference effect (Brady, 2004). Perhaps practicing tasks that manipulates both the muscle motor program and force motor program might expose the contextual interference effect for a complex task. Results from Goode and Magill (1986) demonstrated support for this by having participants practice three different serves from two different locations.

Attention

In addition to practice schedules, another component of learning deals with how a novice is directing attention to execution of the task during initial stages of learning. Previous studies investigating the contextual interference effect have incorporated components such as knowledge of results and expertise differences, however, to our knowledge; no study has investigated practice schedules with the additional component of focusing attention. As previously discussed, not only is the organization of practice important in order to retain and learn the information, but directing the novice's attention to the right things might help to increase the learning process even more.

Theories of attention have shifted since the 1950's. One important theory is the central capacity theory, which assumes that attention has a fixed capacity and when performing multiple tasks simultaneously, attention given to the primary task decreases (Norman & Bobrow, 1975). This theory demonstrates an individual's ability to focus on a primary task of interest, and at the same time try and perform a secondary task to observe the amount of interference on the primary task. The secondary task can be discrete or continuous task, and is usually presented visually or vocally. For example, Welch (1898) had subjects perform a primary task of handgrip strength while simultaneously performing other tasks such as reading, writing, math, visual, and auditory perception tasks. Results demonstrated that handgrip strength was strongest when performed independently, however when handgrip strength was assessed while performing the secondary tasks, there was interference thus decreasing the handgrip strength (Welch, 1898). This methodology has been used to assess attention differences in experts and novices. For example, Beilock et al. (2002) used a golf putting task, and theorized that experts who demonstrate proceduralized knowledge of a skill do not require constant attention; therefore additional attention is available for performing a secondary task. Novice and experienced golfers were recruited and practiced a golf putting task. The interest of the study measured the attention differences between a novice and expert, in addition to how attention demands would change for experts when exposed to a novel "funny" putter (a modified and differentially weighted putter), since this was unfamiliar.

There were three golf-putting task conditions that both the expert and novice performed. This included a single-focus task, dual-focus task, and skill-focus task. The single task putting condition consisted of putting normally from different locations using both putters. After, subjects listened to a series of words, and upon hearing the target word, were required to repeat it out loud every time they heard it. In a dual-task condition, in addition to performing the putting task, participants were instructed to listen for a target word and repeat it out loud while they were putting. Results demonstrated that novices using the regular putter and funny putter, in addition to experts using the funny putter, performed worse in the dual-task putting condition. Because experts were not used to using the funny putter, this was considered a new task, and more attention was directed to the skill instead of monitoring the words (Beilock, Wierenga, et al., 2002). Experts in the dual-task condition performed better than novices when using the regular putter, suggesting less attention required for performing the primary task of putting.

While performing a primary and secondary task, of particular interest is where the learner is actually focusing or directing their attention. This can be in two different ways;

internally, on the skill movement, or externally, on the outcome of the skill. The internal and external focus of attention theory suggests that if an individual is focusing internally, the attention is directed towards the learner's body movements while performing the task. If the learner is focusing on something in the environment and not on the skill movement, but instead the outcome of the skill, the learner is focusing externally. External and Internal focus of attention dates back to Cattell and Bernstein (1940), who originally thought that only an expert would benefit from an external focus, or focusing on the movement outcome or a factor in the environment. In contrast, novices should perform better with an internal focus of attention, focusing on body and skill movements, especially for learning new tasks to get a feel of the movement. Studies have demonstrated that by giving an expert an internal focus of attention, the natural execution of the already well learned skill decreases (Wulf & Su, 2007).

Measuring attention while executing the movement of a skill has been done by using a probe technique that directs attention to either the skill movement or the outcome of the skill movement (Beilock, Carr, MacMahon, & Starkes, 2002; Gray, 2004). It has also been done by verbally communicating with the subject where to focus their attention (Wulf, et al., 1998). Wulf and colleagues have demonstrated that by giving even a novice directions to focus on something externally, or on something in the environment, promotes better learning than giving a novice instructions to focus on something internally, such as skill movement. For example, Wulf et al. (1998) required subjects to perform a ski type movement on a ski simulator. The task was to move the platform of the ski simulator as far left and as far right as possible. The further subjects could move the platform, the higher amplitudes they would produce, demonstrating an increase in performance of the task. Experimenters verbally communicated to participants where to focus attention, which was either internal or external. The internal focus instructions were to ‘exert force on the outer foot,’ encouraging learners to focus on skill movements or on something the body is doing. The external focus instructions were to ‘exert force on the outer wheel,’ which encouraged learners to focus on something in the environment or away from the body (Wulf et al., 1998). In addition, a control group was not given any instructions. After two days of practice, learners were given a retention test on the same task. Results revealed the external focus group, or those focusing on something in the environment, demonstrated larger amplitudes than the internal focus group, signifying the external group to have superior performance to that of the internal group. In a second experiment, a different task was used to see if this phenomenon could be generalized. It was a simple balance task, and the internal focus group was instructed to keep their feet at the same height, and the external focus group was instructed to focus on keeping red markers at the same height. Results from the retention test revealed the external group to have superior balance than the internal group.

Wulf et al. (2007) investigated how cueing learners to focus either internally or externally would benefit when learning a complex motor task using only novices. The task was to hit golf balls to a target by practicing the pitch (chip) shot, and points were awarded based on where the ball landed. Novices received either external or internal instructions on where to focus attention while executing the skill, and were then compared to a control group receiving no instructions. Instructions for the internal group encouraged learners to focus on the movement of their arms while performing the pitch shot. The external group was instructed to focus on the head of club while performing the pitch shot. One day later, a retention test was given. Results demonstrated that the external focus group, or those who focused on the club head, was more beneficial for learning for the novice. However, focusing on the head of the club might be controversial as to whether or not this was really external focus. The head of the club correlates to the swing execution. Perhaps a better cueing would have been to focus on the target.

Arguments have been made against theories of attentional focus during execution of the skill. Retention tests are typically done minutes later in order to assess if learning takes place. This might not be a sufficient amount of time for measurement of a retention test (Walker, Brakefield, Hobson, & Stickgolf, 2002). The other argument is the lack of manipulation checks implemented throughout the duration of the experiment. If specific instructions are given to the learner on where to focus attention, how does the experimenter know whether or not the learner is actually focusing attention to where they were instructed? Just because a learner is instructed to focus on something in the environment or on a specific body movement, does not mean the individual is in fact directing their attention there. Wulf and colleagues have demonstrated that by giving both an expert and novice an internal focus of attention, performance will degrade during skill execution. However, if an expert is performing an already well learned skill, why would the expert focus on something other than what they already know (Gray, 2004)? Failure to use manipulation checks such as a verbal report or interview technique to question on where the learner is focusing attention seems to be required when verbally communicating to a learner on where to focus attention.

A more direct measure of attention different than verbally communicating to the subject where to focus attention is using a primary and secondary task to direct attention inward or outward. Beilock et al. (2002) hypothesized that experienced golfers performance should not decrease for dual tasks because the primary task of putting is automatic (e.g., the secondary tone will not disrupt performance). By using the dual task method, a secondary task can be implemented that will draw attention either to skill movement, or serve as a distractor away from skill movement. If the secondary task is directed away from skill movement for experts, there should not be a decrease in performance. However, if the secondary task is manipulated so that attention is inward, an expert's performance of the well learned skill should decrease, since they already demonstrate proficient movement without having to rely on declarative knowledge.

Expert golfers putted from nine different locations. Two groups were split so that experts were either in the skill focus group or the extraneous focus group. The skill focus group had to verbally state when the club head came to a stop, by saying out loud the word, 'stop'. For extraneous focus, subjects listened to a series of words that were playing while executing the putt. They were instructed to identify the target word that was randomly presented by repeating the word out loud. The results demonstrated expert golfers to perform better in the extraneous focus condition compared to the skill focus condition. These results suggested that by giving experts an inward focus of attention, the performance of the task decreased.

In the second experiment, the main interest of this study was how this methodology applied to novice and expert soccer players performing a soccer dribbling task. In soccer, experts have a preferred foot to manipulate the ball, and in some cases when experts are required to perform a skill with the non-preferred foot, performance of the skill can decrease. The task in the present experiment was to dribble through a series of cones with both the right and left foot. Both the novice and expert soccer players performed both the skill focus and extraneous focus conditions. In the skill focus task, subjects responded to a randomly presented tone and verbally said out loud what part of the foot (inside or outside) was in contact with the ball when the tone was presented. For the extraneous task conditions, subjects had to listen to a series of words, and upon hearing the target word, identify and repeat it out loud when it was presented. Results demonstrated that during practice, experts performed better than novices. Novices did not differ in performance between the right and left foot, while the experts were faster with their right foot than left foot. For extraneous focus, experts performed better than novices in the right-foot dribbling conditions. In the skill-focus conditions, performance of the experts and novices were not different, suggesting that the inward focus for the experts significantly decreased performance, however did not affect the performance of the novice. Novices performed better in the skill-focus conditions, or when attention was directed inward, which goes against the findings proposed by Wulf and colleagues suggesting that an internal focus is not beneficial for novices. An even more particularly interesting part of the study is that for the left foot, even though experts performed better than novices with extraneous and skill-focus, both groups performed better in the skill-focus condition. This finding suggests that by directing the experts attention inward on movement of a skill that is not automatic (left-foot dribbling) was beneficial compared to directing the attention outward.

Gray (2004) replicated these findings in a simulated baseball task. The task was to hit the ball, in addition to responding to a random tone. There were three conditions; single task, skill focused task, or extraneous focused task. The single task condition required the participants to hit the ball. The skill focused task required the participant to indicate whether the bat was moving up or down at the time the tone was randomly presented. The extraneous task required participants to verbally state a target word upon hearing a random tone. Ten experts and ten novices were used to compare how directing the attention either inward or outward would benefit the two groups. Experts performed better in the extraneous dual task, but worse in the skill focused task, while the novices performed worse in the extraneous dual task, and better in the skill focused task. The results from Beilock and Gray (2012) provide manipulation checks and superior assessments of where a learner is directing attention, and that directing attention inward while performing a skill does not disrupt performance for a novice.

One argument made with this methodology included the number of choice-responses for both groups. For example, in the golf putting task the skill focus group was required to say "stop" at the end of the putt while the extraneous focus group had to constantly monitor a series of words and repeat the target word out loud (Beilock, Wierenga, et al., 2002). Therefore, Beilock and Gray (2012) had the skill focus group identify the movement of the swing upon hearing a random tone by indicating if the club was moving “backward” or “forward”. The extraneous focus group had to identify if a random tone was “high” or “low”. Results from this study also supported novices to perform better in skill focus conditions compared to experts.

However, Suss and Ward (2010) increased the difficulty of the secondary task (based on a suggestion by Rob Gray) and had 3 choices instead of 2. In this study observing novice and experts in a rifle shooting task, participants had to indicate (upon hearing a random tone) if the finger was “on”, “off”, or “in”. The extraneous focus group had to identify if the tone was “high”, “low”, or “medium”. This study demonstrated no differences between a novice and expert for extraneous and skill focus conditions.

Purpose of the Study

Many factors go in to learning a new skill, specifically the amount of interference and attention, during skill movement. Based on the review on practice conditions and attentional focus, the present study attempts to address how the two interact. This study is of particular interest for many reasons. One, it will provide a clearer understanding of the contextual interference effect by comparing a previously validated multi-joint arm movement key pressing task, and compare it with a previously validated complex task of golf putting. It will expose learning effects by providing immediate and delayed retention tests. It will gain insight as to how a novice learning a new task directs their attention during performance, and what practice conditions will be most beneficial for learning a new skill. Specifically, what are the optimal practice schedule conditions and how should attention be directed in order to learn a new skill and retain the information to promote effective learning? In addition, is there a difference when performing a multi-joint arm movement task, compared to a complex task in the sport domain? The way these research questions will be carried out is by replicating previously validated methodology successfully demonstrating the contextual interference effect, in addition to the methods used by Beilock and Gray (2012) using the probe technique to direct attention to skill movement or away from skill movement. As mentioned before, for discrete tasks the contextual interference effect is strongest when manipulating the relative timing (or general motor program) while keeping the overall duration (parameters) the same. Lee, Wulf and Schmidt (1992) manipulated the relative timing, though the contextual interference effect was not found, they proposed the task used in their experiment was too difficult. Wright (2005) simplified the task by using two movements with different relative timings and found a strong contextual interference effect. Therefore, the present study uses these methods and incorporates a secondary task to measure attention. The complex golf putting task uses methods similar to Porter (2005), however in addition to manipulating the force motor programs (e.g., the distance away from the target), the muscle motor program will be manipulated by using the long putt or belly putt technique. Therefore, putting will take place from 2 different locations using 2 different golf putting swings, and organization of the distance and swing will be similar to previous methods used by Meira and Tani (2001). For example, subjects will use the long putt technique and shoot from the short distance and long distance, or subjects will use the belly putt technique and shoot from the short and long distance (conditions; LS, LL, BS, BL). These swings and distances will be arranged in either a blocked or random order.

Attention conditions will include a skill-focus and extraneous-focus condition with 3 tones (Suss & Ward, 2010). Upon hearing a random tone, the distraction from the tone will direct attention to the skill movement for the skill-focus group. For the extraneous-focus, the distraction from the tone will direct attention away from the movement. Both groups will have the same amount of choices to respond to in order to keep the number of choice-responses the same. The extraneous-focus group will respond to a random tone that is high, medium, or low. The skill-focus group will indicate the direction the finger is moving by saying “up”, “over”, or “still”, or indicate the direction the club is moving which is either “backward”, “forward”, or “still.”

For practice independent of attention, it is hypothesized that a contextual interference effect will occur for both the discrete and complex tasks. Subjects in the random group will have inferior performance during skill acquisition, but superior performance on both immediate and delayed retention tests. Those practicing in a blocked condition will demonstrate superior performance during skill acquisition but inferior performance during both immediate and relayed retention tests.

It is suggested that presenting large explicit knowledge is not effective for retaining the skill (Liao & Masters, 2001; Masters, 1992). With attention, Prinz's (1990) common coding principle states that afferent and efferent information (instructions) exposed to the learner should be compatible, and that movements should be based on the desired outcome. Maxwell and Masters (2002) propose that individuals do not rely on one attentional focus, and can switch attention according to task demands. They also propose that individuals who focus on something in the environment are drawn to only one source of information (e.g., the putting green). However, when an individual is focusing internally, not only are they attending to skill movement, but they are also taking in additional resources from the environment (such as where a golf ball lands after a putt), therefore, internal instructions cause a greater load on working memory (Maxwell, et al., 2000) Thus, when a secondary task is introduced, performance degrades (Maxwell, et al., 2000).

With this information, for attention independent of practice, novices directing their attention both inward and outward will experience greater explicit knowledge by responding to the sound of the tone and then switching attention back to the primary task.

However, this explicit knowledge will either aid the learning process or disrupt it. It is hypothesized that efferent information presented from the tone for extraneous focus will be more compatible to the skill movement, and subjects will be able to respond to the tone and continue with the primary task compared to the skill focus group, who should experience afferent information to be less compatible to the skill movement (and experience greater demand of attention by attending to hearing the tone, thinking about the skill movement, and processing external information such as results). It is hypothesized the extraneous-focus group will have increased performance during acquisition compared to the skill-focus group, and will maintain the ability to shift attention back to the primary task of interest, causing the learner to engage in an increased thought process during the acquisition period. This will increase performance on retention tests. It is hypothesized that those in the skill-focus group will experience a greater load on working memory, with afferent information being less compatible to the skill movement compared to the extraneous-focus group; therefore performance will be minimal during acquisition. The large explicit knowledge consisting of afferent information to be less compatible with skill movement will disrupt the learning process, and inferior performance will be demonstrated on a retention test.

For attention and practice as an interaction, since there is a predicted contextual interference effect, in addition to extraneous-focus increasing learning and superior retention scores, it is hypothesized that the group with extraneous-focus during a random practice schedule will demonstrate a slower rate of learning during the acquisition period. Those practicing in a blocked practice in the extraneous conditions will demonstrate superior performance during the acquisition period. However, those practicing randomly in the extraneous-focus condition will have superior retention scores compared to all other groups. It is hypothesized however that those practicing with extraneous focus in the blocked group will still maintain scores compared to skill-focus groups.

Methods

Participants

Participants were undergraduate students from Michigan Technological University (task 1; n=48, age; 21.54$\pm$3.25, task 2; n = 56, age; 21.61$\pm$3.34). For the first task, 12 subjects were discarded from the study due to an inability to follow directions. For the second task, 4 subjects were discarded because they did not meet the following criteria for golf putting: 1) no previous experience with golf or 2) did not play miniature golf in the past four years. Subjects were volunteers and unaware of the aims or the purpose of the study. The study was approved by Michigan Technological University's Institutional Review Board and informed consent was given.

Apparatus

E-Prime. The key pressing task was performed on a standard computer with a numeric keypad. The task stimuli and knowledge of results were presented on a computer monitor. The program used was the E-prime software from Psychology Software tools (Psychology Software Tools, Inc., Pittsburgh, PA).

Golf putting. A simulated golf putting green was set up with a circular target 15 centimeters in diameter. Subjects were required to putt as closely as possible to the center target from two different locations of either 0.9 or 1.82 meters (Porter & Magill, 2005). Around the center target was an additional target placed 15 centimeters in diameter around the previous circular target. A total of 6 circles were placed around the center target (see figure 1). Based on where the golf ball stopped, points were awarded, with 0 points awarded when the ball stopped at the desired center target.

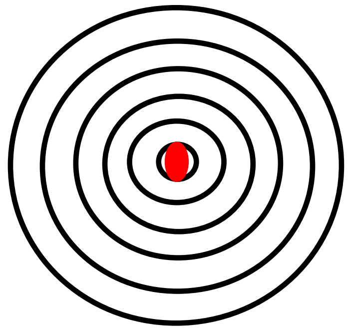

Figure 1.1 *The target for the golf putting task. If the golf ball landed in the center target, a score of 0 was given. An additional point was given if the ball landed in the circle outside of the center target. Anything outside the designated area included 6 points.*

Procedure

The task performed first was counterbalanced across participants, so that half the subjects performed the golf putting task first, and the other half of subjects performed the key pressing task first.

Key Pressing. Subjects were instructed to sit in a chair at a comfortable position in front of the computer monitor. Using the dominant hand, subjects were required to perform the number sequence, “2-6-5”, where the subject held down the “2” button, and upon seeing a warning stimulus, release the “2” button and push “6” and then “5”. The object was to move from the “2” button to the “6” button in a certain amount of time, and move from the “6” button to the “5” button within a certain amount of time, depending on the task code. The sequence was to be completed within the total movement goal time of 800 milliseconds. Subjects performed two different tasks, and the task presented on a computer monitor indicated the amount of time between the first movement (2-6) and the second movement (6-5). The relative timing for the first and second movements was either 25% or 75% of the total movement time (manipulating the general motor program). The task code was presented as either 25S or 75S. Task code 25S allocated 25% of the total movement time to the first movement (2-6), and 75% of the total movement time to the second movement (6-5). Therefore, subjects were required to release the “2” button and push the “6” button in 200 milliseconds, then release the “6” button and push the “5” button within 600 milliseconds. In contrast, 75S allocated 75% of the total movement time to the first movement, and 25% of total movement time to the second movement. Therefore, subjects are required to release the “2” button and push the “6” button within 600 milliseconds, then release the “6” button and push the “2” button in 200 milliseconds. Knowledge of results were provided after every trial. Table 1 provides a clearer explanation of the progression.

Table 1. Task goals (movement time in milliseconds) (25%) = 200

Task	Goal movement time 1 in ms; release “2” and push “6”	Goal movement time 2 (ms), release “6” and push “5	Total movement time (ms) to complete the entire sequence, “2-6-5”
25S	(25%) = 200 ms	(75%) = 600 ms	(200+600ms)=800 ms
75S	(75%) = 600 ms	(25%) = 200 ms	(600+200ms)=800 ms

Baseline. Baseline measurements were obtained for the key pressing task which included 4 trials of each task (25S and 75S). This was an appropriate amount to avoid learning effects.

Acquisition. Two blocks of 32 trials were completed, for a total of 64 acquisition trials. Based on the group assigned, subjects performed task codes in either a blocked or random order. Those in the blocked group performed 32 trials of one task code, and then 32 trials of the second task code. Those in the random group performed both task codes in a random order for the total 64 acquisition trials, with the exception being that within a block of 8 trials, task code 25S and 75S appeared no more than 4 times.

Attention. Subjects were split in to either a skill-focus condition or extraneous-focus condition. Subjects in the skill-focus condition were required to indicate the direction the finger was moving upon execution of the key pressing sequence. The three choices were 'up', 'over', or 'still.' Those in the extraneous-focus conditions were required to respond to a random tone by saying if the tone was "high", "medium", or "low".

Golf putting. Subjects were required to putt a golf ball from two locations (0.9 or 1.82 meters) to a circle target. The task was to putt the golf ball as close to the center target as possible. Around the center target were an additional 5 targets separated by 15 centimeters in diameter. If the ball stopped on the center target, a score of 0 was given. The lower score indicated better accuracy of the putt.

Baseline. Baseline measurements were obtained for the golf putting task that included 5 trials of each putting technique from the appropriate location for a total of 20 putts.

Acquisition. Subjects were required to putt from the two different locations, using two different putting techniques, so that 25 trials of each grip from the two distances were performed for a total of 100 putts. The two different putting techniques were the long putt and belly putt, and the two different distances were long and short (long putter + short distance; LS, long putter + long distance: LL, belly putter + short distance; BS, belly putter + long distance; BL). Those practicing in the blocked group performed 25 putts using the same grip from the same location before moving on to the next distance. Those practicing in the random practice condition practiced all 4 variations in a random order, so that of a block of 8 putts, 2 of each of the grip paired with the short or long distance was performed no more than two times. Therefore, subjects performed the belly putt from the short distance before moving on to the long distance, then performed the long putt from the long distance before moving on to the short distance.

Attention. Attention conditions were identical to the key pressing task, with the only exception being the skill focused group was required to state if the club head was moving “forward”, “backward”, or “still”.

Retention Phase. Upon completion of the final task, subjects performed an interpolated activity that was considered a “cool down” period for five minutes. After, an immediate retention test was given for both the E-prime and golf putting tasks. The golf putting task consisted of 10 putts from each location using both swings in an alternating order, so that 20 total putts were performed. For the E-prime task, subjects performed 16 trials of each task code so that a total of 32 trials were completed. Knowledge of results were not provided.

Delayed Retention. A delayed retention test was given the next day. The retention test was considered delayed given 1) it was at least 16 hours since the immediate retention test and 2) the participant had a full night sleep (Walker, et al., 2002).

Statistical Analysis

Key Pressing.

Baseline. Baseline data was collected that included 4 trials of each task (25S and 75S). Baseline data included performing a one way ANOVA to assess differences between groups.

Acquisition. A 2 (practice; blocked/random) x 2 (attention; internal/external) x 8 (trial block) mixed ANOVA with repeated measures on the trial block was performed across groups for relative timing error (RTE), and constant and variable error combined (CEVE). Both of these dependent variables are predictors of accuracy for the goal proportion times of 600ms or 200ms, and overall time of 800ms. In addition, a 2 (practice; blocked/random) x 8 (trial block) mixed ANOVA with repeated measures on the trial block was performed to assess practice conditions independently. A 2 (attention; skill/extraneous) x 8 (trial block) mixed ANOVA with repeated measures on the trial block was conducted to assess attention as an independent factor on the trial blocks. A Bonferonni adjustment was used when differences were detected.

Retention. A 2 (practice; blocked/random) x 2 (attention; skill/extraneous) x 4 (trial block) ANOVA with repeated measures on the trial block was performed for relative timing error and constant error and variable error to detect differences between groups. In addition, separate 2 way ANOVA's with repeated measures on the trial block was used to detect differences between practice and attention conditions. A Bonferonni adjustment score was used when differences were detected.

Posttest scores. A repeated measures ANOVA was used to compare scores collected from baseline measurements to post test scores.

Golf Putting.

Baseline. Baseline data was collected which included 20 putts, or 5 of each putt (BL, BS, LL, LS). A one-way ANOVA was used to detect if there were any differences between groups.

Acquisition. A 2 (practice; blocked/random) x 2 (attention; internal/external) x 10 (trial block) mixed ANOVA with repeated measures on the trial block was performed across groups for scores obtained from golf putting. In addition, a 2 (practice; blocked/random) x 10 (trial block) mixed ANOVA with repeated measures on the trial block was performed to assess practice conditions independently. A 2 (attention; skill/extraneous) x 10 (trial block) mixed ANOVA with repeated measures on the trial block was conducted to assess attention as an independent factor on the trial blocks. The scores obtained from golf putting were the dependent measures for both attention and practice as independent conditions. If the golf ball stopped in the center target, a score of 0 was given. An additional point was given if the golf ball landed on the second circle, and so forth. A Bonferonni adjustment was used when differences were detected.

Retention. A 2 (practice; blocked/random) x 2 (attention; skill/extraneous) x 4 (trial block) mixed ANOVA with repeated measures on the trial block was performed for scores obtained from golf putting. In addition, a 2 (practice; blocked/random) x 2 (attention; skill/extraneous) x 2 (putt; long/belly) x 2 (distance; long/short) mixed

ANOVA was ran to detect any interactions between practice and attention. A Bonferonni adjustment was used when differences were detected.

Posttest. A repeated measures ANOVA was used to compare scores collected from baseline measurements to post test scores.

Results

Key Pressing. Baseline data revealed no differences between groups before performing the key pressing task (see table 2).

Table 2. Overview of the baseline data collected between each group. 25S or 75S represents the task, RTE or CEVE represents the dependent variable.

25S RTE	25S CEVE	75SRTE	75SCEVE
$F(1,3) = 1.89$, $p>0.05$	$F(1,3) = 2.72$, $p>0.05$	$F(1,3) = 2.86$, $p>0.05$	$F(1,3) = 2.54$, $p>0.05$

Acquisition trials for relative timing error for the three way interaction revealed a Block and Practice interaction ($F(1,7) = 4.76$, $p<0.05$). Those practicing in a blocked practice condition demonstrated improvement from trial block 1 to 4, and improvement from trial block 4 to 8 ($F(1,7)=6.91$, $p<0.05$) . For random practice, there was not a clear improvement across all trials from trial block 1 to 8 ($F(1,7)=0.65$, $p>0.05$). Significant differences were found between practice ($F(1,7) = 9.76$, $p<0.05$, $d=0.53$). Those practicing in a blocked practice condition were superior to those practicing in a random condition. For constant and variable error combined there was a Block, Practice, and Attention interaction ($F(1,7)=2.1$, $p<0.05$). Those practicing specifically in the blocked extraneous group demonstrated significant improvement across trial blocks ($F(1,7) = 7.48$, $p<0.05$, $d=0.13$). In addition, there was a Block and Practice interaction ($F(1,7) = 4.25$, $p<0.05$). There were no differences between trial blocks for random practice ($F(1,7)=1.23$, $p>0.05$). For blocked practice, there was clear improvement across trial blocks 1 to 4, then upon learning the new task, there was clear improvement from trial block 5 to 8 ($F(1,7)= 7.12$, $p<0.05$). See figures 2.1 and 2.2 for a summary.

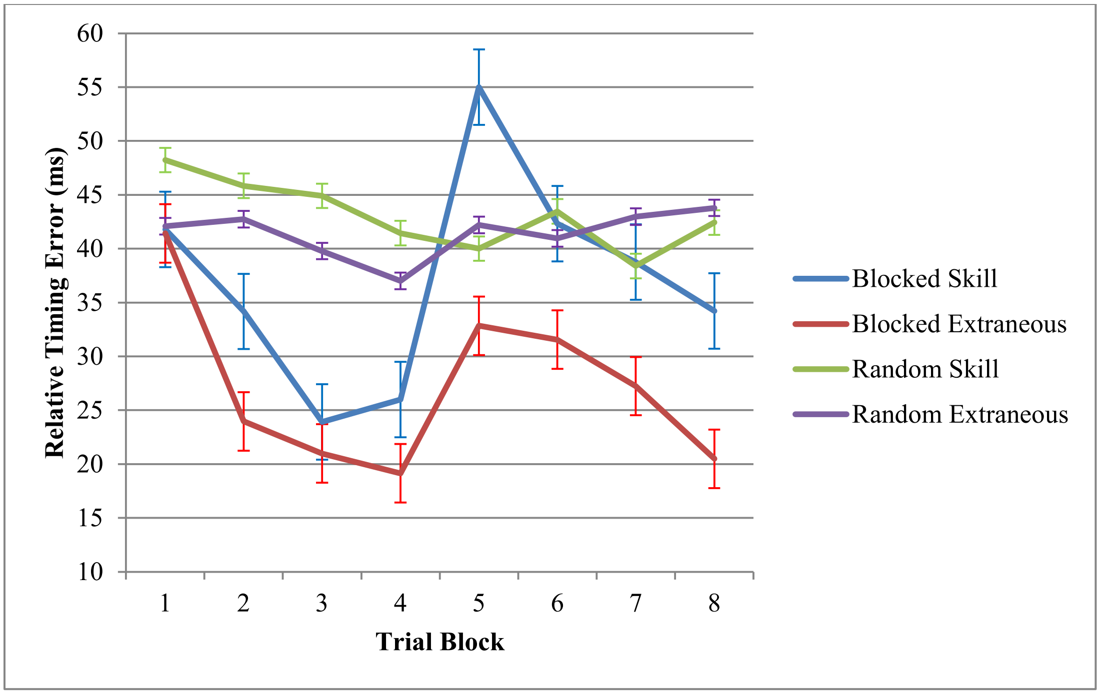

Figure 2.1. *Relative timing error (mean ± standard error) scores obtained during acquisition over the 8 trial blocks.*

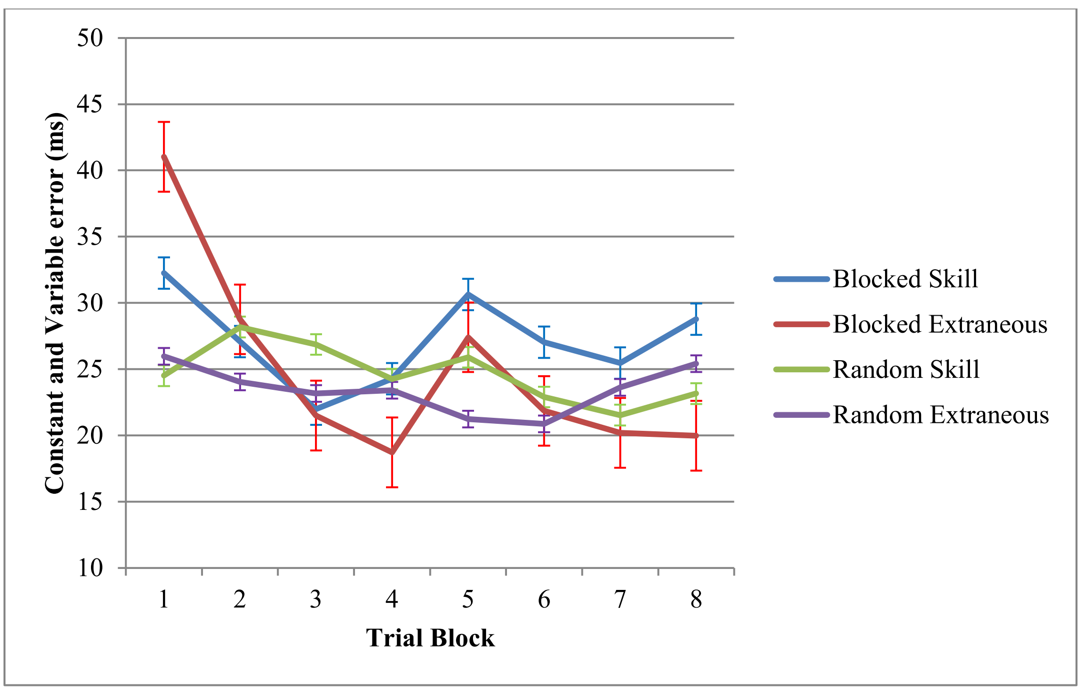

Figure 2.2 *Constant and variable error (mean ± standard error) during acquisition over the 8 trial blocks.*

Immediate retention revealed a difference between practice conditions. Those practicing in a blocked practice had improved relative timing error scores compared to random practice ($F(1,1)=4.47$, $p<0.05$, $d=0.46$). For delayed retention for constant and variable error, there was a significant difference between attention conditions. Those practicing with extraneous-focus had improved constant and variable error scores compared to the skill-focused group ($F(1,1)=5.79$, $p<0.05$, $d=0.30$). In addition, there was a Practice and Attention interaction. Those practicing in the blocked practice with extraneous focus demonstrated superior constant and variable error scores compared to all other groups ($F(1,1)=6.65$, $p<0.05$, $d=0.32$). See figure 3.1 and 3.2 for a summary for immediate retention, and figure 3.3 and 3.5 for a summary of delayed retention.

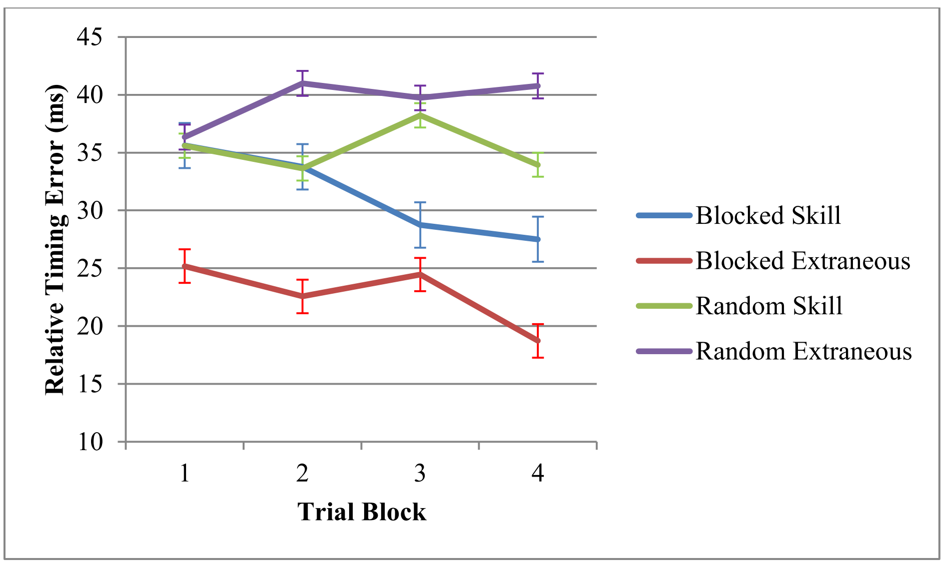

Figure 3.1 *Immediate retention (mean ± standard error) for relative timing error.*

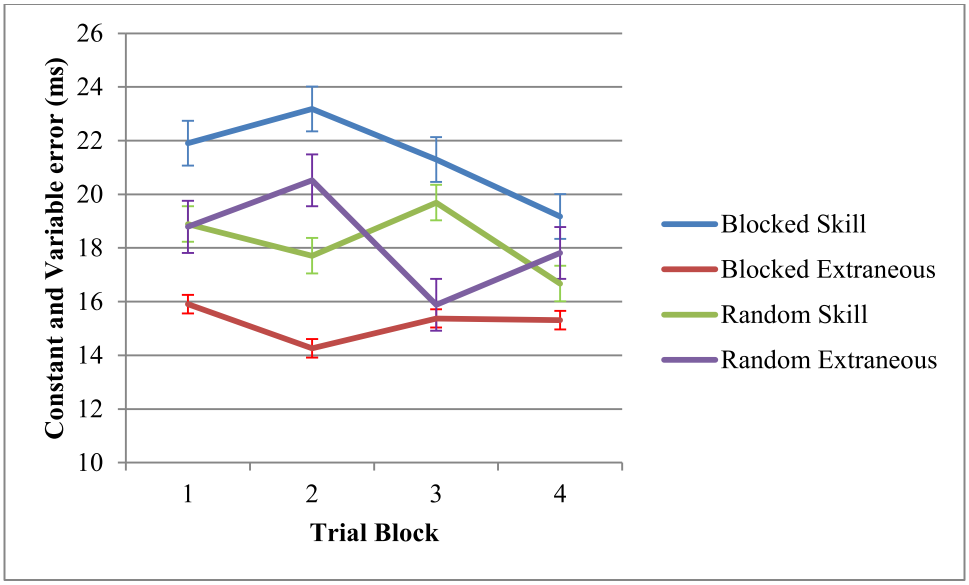

Figure 3.2 *Immediate retention for constant and variable error (mean ± standard error).*

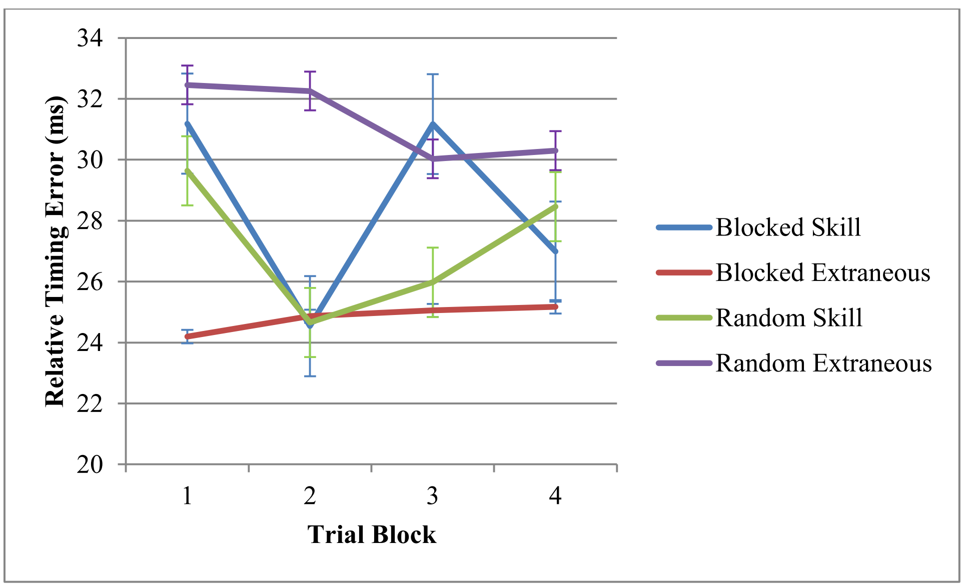

Figure 3.3 *Delayed Retention Scores for relative timing error (mean ± standard error).*

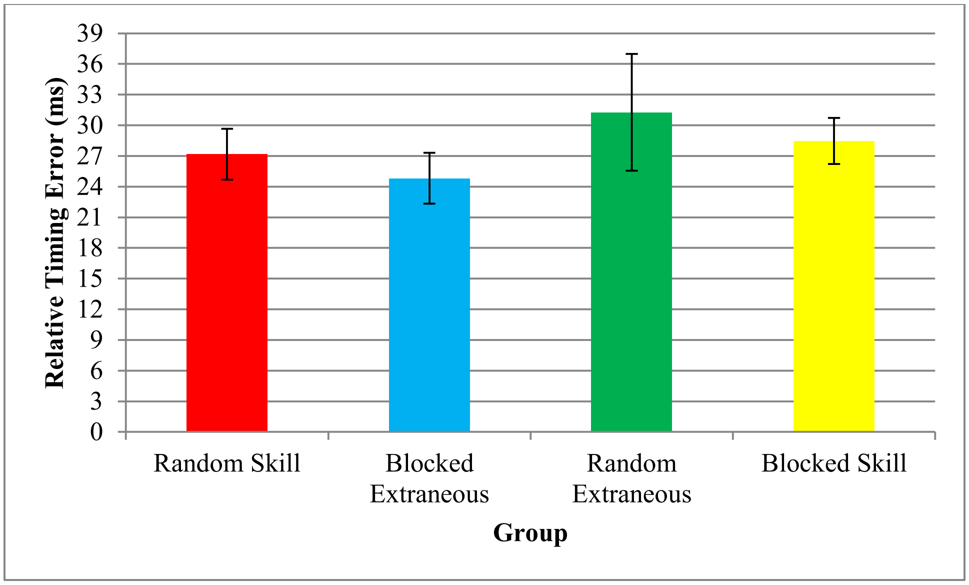

Figure 3.4 *Delayed Retention scores for relative timing error (mean ± standard error) for all trial blocks.*

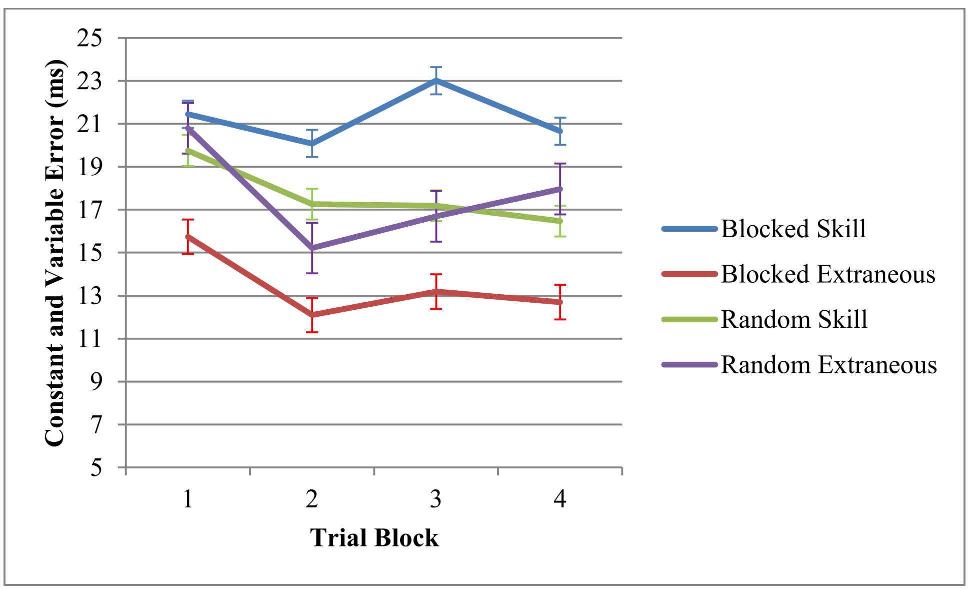

Figure 3.5 *Delayed Retention scores for constant and variable error (mean ± standard error) across trial blocks*

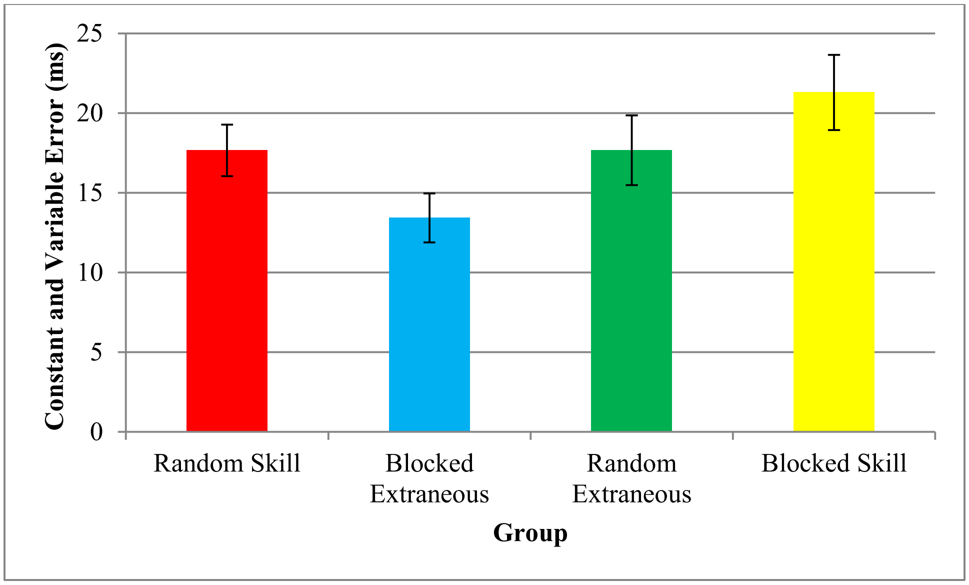

Figure 3.6 *Delayed Retention scores for constant and variable error (mean ± standard error) for total trials.*

Golf Putting. Baseline data revealed no differences between groups for each putt (see table 3).

Table 3. Baseline data collected for each group for each putting condition.

Long putt/Short distance	Long putt/Long distance	Belly putt/Long distance	Belly putt/Short distance
$F(1,3) = 0.96$, $p>0.05$	$F(1,3) = 1.70$, $p >0.05$	$F(1,3) = 0.41$, $p>0.05$	$F(1,3) = 0.25$, $p>0.05$

For the three-way interaction, the Greenhouse-Geisser correction was used for the F ratio. Results demonstrated that during acquisition for the three-way interaction there was a Block and Practice interaction ($F(1,7.30)=6.23$, $p<0.05$) and a Practice and Attention interaction ($F,(1,7.23)=0.68$, $p<0.05$). Those practicing in a blocked and extraneous-focus condition had significant improvement from trial block 3 to trial block 9, and were able to maintain the improvement in trial block 10. Those practicing in the blocked and skill-focused group had significant improvement from trial block 6 to 10. For those practicing in the random and skill-focused group, there was not a clear improvement across trials, demonstrating an increase in performance from trial block 1 to 6, and were eventually able to maintain decreased scores in trial block 10. For the random extraneous group, there were only differences between trial block 10, compared to 2, 5, and 7 (see figure 4.1 for a summary). The practice and attention interaction demonstrated an advantage to those practicing in a blocked practice condition with extraneous focus, and random practice with skill focus.

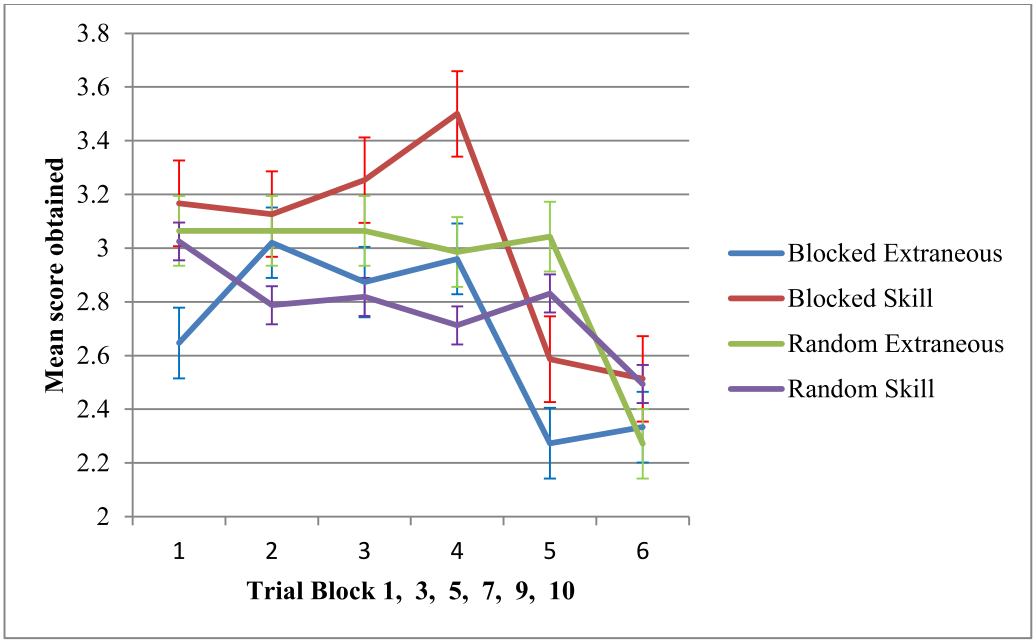

Figure 4.1 *Acquisition trials for golf putting (mean ± standard error).*

For immediate and delayed retention, each putting technique from each distance was analyzed separately to determine if there were group differences for learning each putting technique. Results from the three way interaction demonstrated an Attention and Practice interaction ($F(1,1)=5.91$, $p<0.05$). For immediate retention, all groups performed better from the short distance, however the random skill-focus group had superior scores for the long putt (see table 4). There were no differences for delayed retention (see figure 4.1 and 4.2 for immediate retention, see figure 4.3 and 4.4 for delayed retention).

Table 4. Delayed retention between each group.

	Random Extraneous	Random Skill	Blocked Skill	Blocked Extraneous
Distance	$F(1,1) = 7.383$, $p<0.05)$	$F(1,1) = 78.72$, $p<0.05$	$F(1,1)=10.41$, $p<0.05$	$F(1,1) = 6.15$, $p<0.05$
Putt	$F(1,1) = 0.73$ $p>0.05$	$F(1,1)=5.73$, $p <0.05$	$F(1,1) = 1.61$ $p>0.05$	$F(1,1) = 0.14$ $p>0.05$

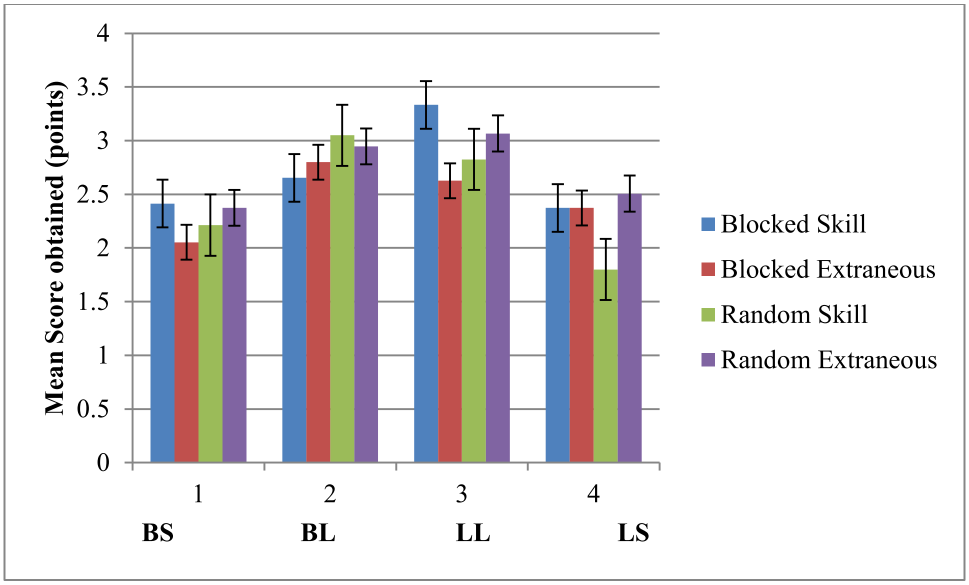

Figure 4.2 *Immediate Retention for each putting condition (mean ± standard error).*

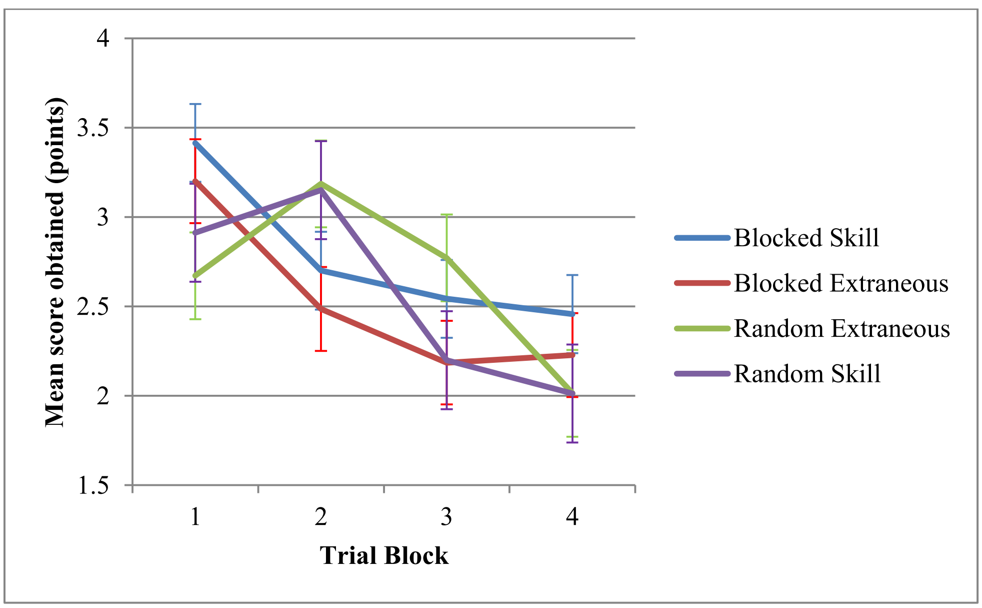

Figure 4.3 *Immediate Retention across trial blocks (mean ± standard error).*

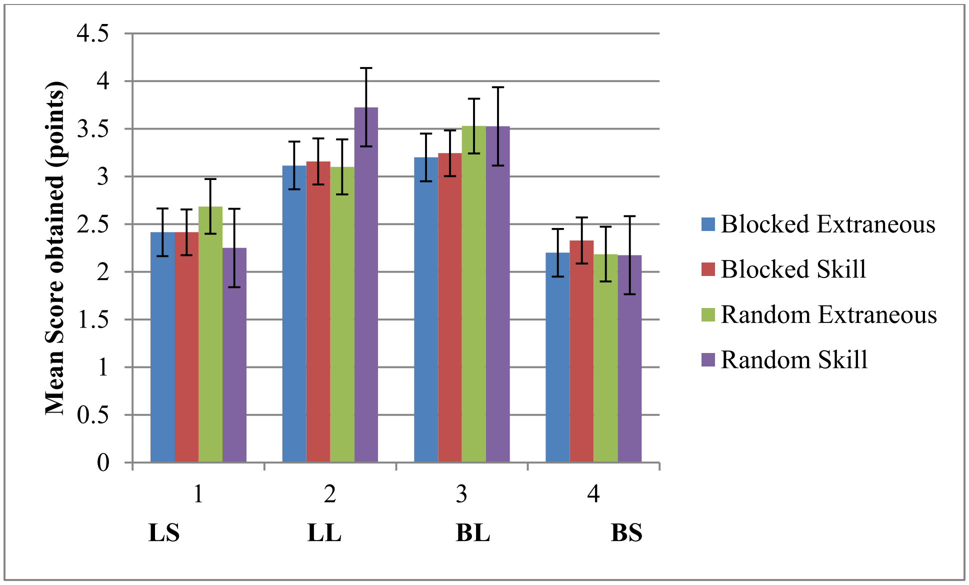

Figure 4.4 *Delayed Retention for each putting condition (mean ± standard error).*

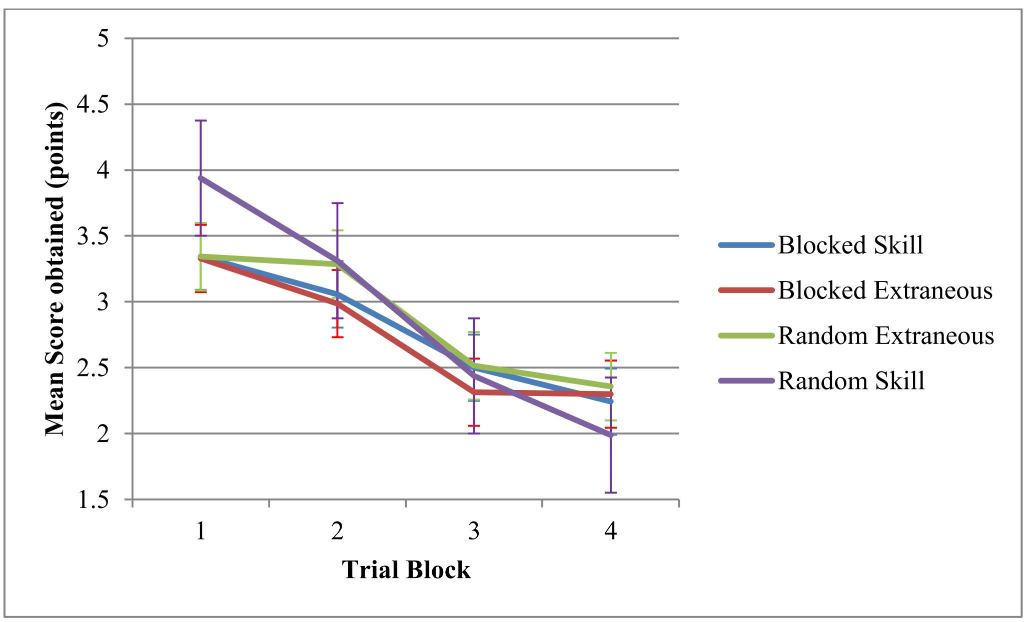

Figure 4.5 *Delayed Retention scores across trial blocks (mean ± standard error).*

Table 5. Reported effect sizes for first trial block and last trial block.

Group	RTE (e-prime) Trial one/ Trial eight	CEVE (e-prime) Trial one/ Trial eight	Mean Score (putting) Trial one/Trial ten
Blocked Extraneous	*d*=1.13	*d*=1.35	*d*=0.09
Blocked Skill	*d*=0.27	*d*=0.24	*d*=0.17
Random Extraneous	*d*=0.09	*d*=0.04	*d*=0.21
Random Skill	*d*=0.32	*d*=0.11	*d*=0.14

Post test scores.

Key Pressing. The blocked extraneous focus group demonstrated significant improvement for 3 of the 4 tasks compared to baseline data. The blocked skill focus group demonstrated significant improvement for one of the tasks. Both random groups did not perform better compared to post test scores (see table 5 below).

Table 6. Posttest scores for each task for each group.

Group	25S RTE	25S CEVE	75SRTE	75SCEVE
Random Extraneous	$F(1,12)=2.48$, $p>0.05$ $d=0.63$	$F(1,12)=0.74$, $p>0.05$ $d=0.69$	$F(1,12)=0.01$, $p>0.05$ $d=0.06$	$F(1,12)=0.01$, $p>0.05$ $d=0.05$
Random Skill	$F(1,12)=0.35$, $p>0.05$ $d=0.43$	$F(1,12)=0.08$, $p>0.05$ $d=0.15$	$F(1,12)=0.24$, $p>0.05$ $d=0.14$	$F(1,12)=0.12$, $p>0.05$ $d=0.19$
Blocked Extraneous	$F(1,12)=9.16$, $p<0.05$ $d=1.67$	$F(1,12)=1.18$, $p>0.05$ $d=0.93$	$F(1,12)=15.9$, $p<0.05$ $d=0.40$	$F(1,12)=4.89$, $p<0.05$ $d=1.06$
Blocked Skill	$F(1,12)=3.20$, $p>0.05$ $d=0.84$	$F(1,12)=0.74$, $p>0.05$ $d=0.41$	$F(1,12)=0.89$, $p>0.05$ $d=1.32$	$F(1,12)=4.89$, $p<0.05$ $d=0.53$

Golf Putting. Those practicing in the random practice with the extraneous focus improved in the long putt from the short distance, belly putt from the long distance, and belly putt from the short distance. Those practicing in the random group with skill focus improved in all putts. Those practicing in the blocked practice condition with extraneous focus improved in the long putt from both distances. Those practicing in the skill-focused group for blocked practice improved only in the long putt from the short distance (see table 7 for a summary).

Table 7. Posttest scores for each putting condition for each group.

	Long/Short	**Long/Long**	**Belly/Long**	**Belly/Short**
Random Extraneous	$F(1,13)=12.5$, $p<0.05$ $d=0.21$	$F(1,13)=0.04$, $p>0.05$ $d=0.01$	$F(1,13)=15.2$, $p<0.05$ $d=0.15$	$F(1,13)=5.96$, $p<0.05$ $d=0.16$
Random Skill	$F(1,13)=7.39$, $p<0.05$ $d=0.24$	$F(1,13)=4.98$, $p<0.05$ $d=0.15$	$F(1,13)=4.71$, $p<0.05$ $d=0.11$	$F(1,13)=19.9$, $p<0.05$ $d=0.25$
Blocked Extraneous	$F(1,13)=39.1$, $p<0.05$ $d=0.22$	$F(1,13)=5.69$, $p<0.05$ $d=0.15$	$F(1,13)=0.46$, $p>0.05$ $d=0.05$	$F(1,13)=0.48$, $p>0.05$ $d=0.05$
Blocked Skill	$F(1,13)=25.7$, $p<0.05$ $d=0.40$	$F(1,13)=1.27$, $p>0.05$ $d=0.09$	$F(1,13)=0.98$, $p>0.05$ $d=0.01$	$F(1,13)=0.01$, $p>0.05$ $d=0.01$

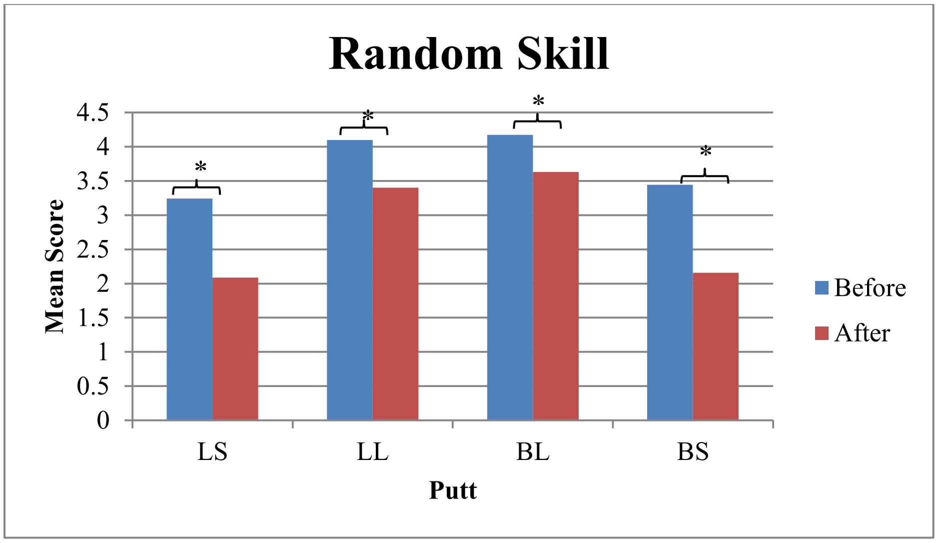

Figure 5.1 *Performance for each putting condition for the random skill group (mean ± standard error).*

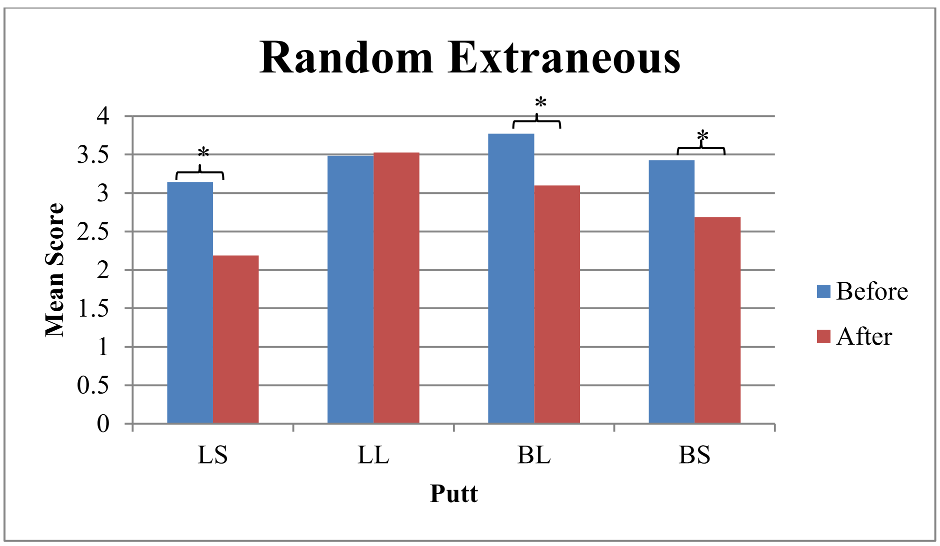

Figure 5.2 *Performance for each putting condition for the random extraneous group (mean ± standard error).*

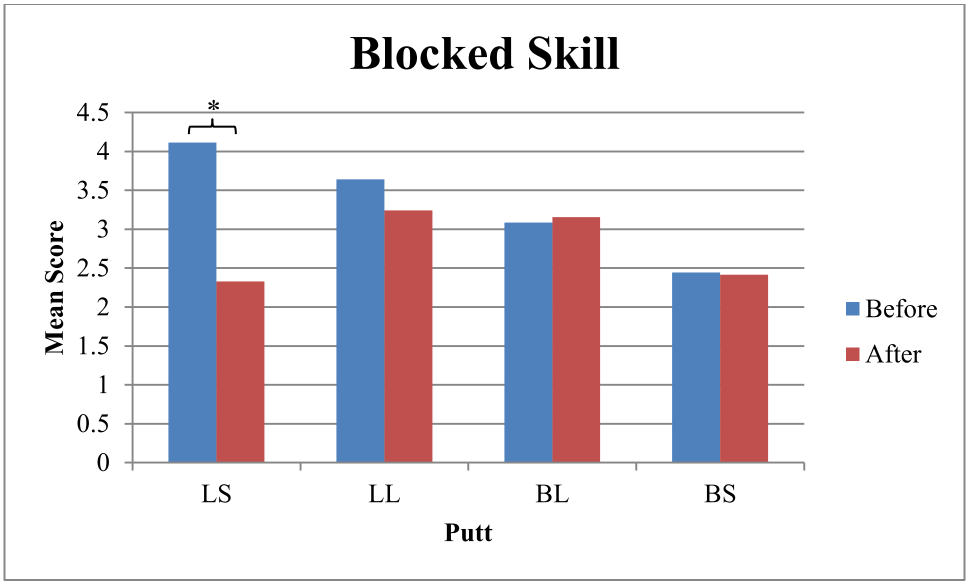

Figure 5.3 *Performance for each putting condition for the blocked skill group (mean + standard error).*

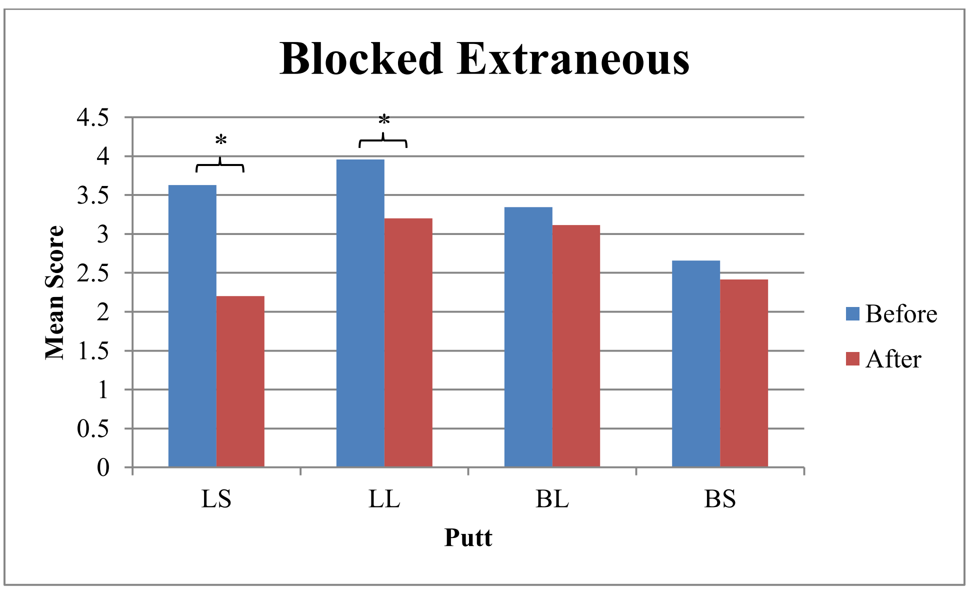

Figure 5.4 *Performance for each putting condition for the blocked extraneous group (mean + standard error).*

Discussion

Practice and attention are key contributors to learning a new skill. For practice, this includes the amount of interference generated during the acquisition process. For attention, this includes attending to actual skill movement, or the outcome of a skill movement. The present study attempted to answer how the two interact when practicing a discrete key pressing task, and a complex golf putting task.

Practice Independent. Increasing the amount of interference generated during the learning process increases retention of a skill when learning a multi-joint arm movement task (Lee & Magill, 1983; Shea & Morgan, 1979). Research has attempted to replicate this finding in complex domains such as rifle shooting (Boyce & Del Rey, 1990). Badminton (Goode & Magill, 1986), and baseball (Hall, et al., 1994), and have been successful in supporting the contextual interference effect. However, much research has failed to support this in complex domains (Bortoli, et al., 1992; Meira & Tani, 2001; Moreno et al., 2003). Two things unfold the contextual interference effect that need to be kept in mind; switching the general motor program (Magill & Hall, 1990) and increasing the amount of interference between tasks (Shea & Morgan, 1979). The present study does this by observing a discrete, multi-joint key pressing task, manipulating the general motor program for relative timing, compared to a complex golf putting task, manipulating the muscle and force motor program.

As hypothesized for the key pressing task, during the acquisition phase the blocked practice group performed better than the random practice group for relative timing error. This supports research investigating discrete tasks and the contextual interference effect, demonstrating blocked practice to be superior during the acquisition phase (Lee & Magill, 1983; Shea & Morgan, 1979). For both tasks 25S and 75S, those practicing with low interference demonstrated clear improvement across trial blocks compared to those practicing with high interference. Individuals who practiced in a random practice condition demonstrated a slight decrease (e.g., improvement) in relative timing error and constant and variable error across trial blocks; however this was not significant between trial blocks. This finding was not surprising however due to the increased interference generated from the random tone (in addition to practice, which will be discussed in a later section). Interference was already generated from random practice, and additional interference was created by having to continuously switch attention back and forth from the primary task of key pressing to the tone.

Castiello and Umilta (1998) demonstrate support for this with volleyball players whose secondary task was to respond to a tone while performing a primary task of receiving a serve. They recorded reaction time from when the tone was played to when participants responded to the tone by saying a target word. These authors found that after the serve was initiated and the volleyball approached the player, there was a decrease in reaction time in responding to the tone during actual skill execution due to the increased attention on performing the primary task. Hence, in the present study the greater attention demands for the primary task for the random group for the key pressing task, regardless if it was skill-focus or extraneous-focus, did not improve for relative timing error or constant and variable error during the acquisition phase due to too much interference generated from responding to the tone, while maintaining the ability to perform the primary task.

Though studies have demonstrated support for immediate retention benefits for a random practice (Shea & Morgan, 1979) the present study demonstrated the blocked group to perform better than the random group for relative timing error. This was not hypothesized, as it was expected a contextual interference effect to occur. However, studies have demonstrated support for immediate retention benefits for blocked practice. Del Rey (1994) had subjects knock down three different movement patterns that represented a specific color; blue, white, and red. The point at which the red movement pattern was to be knocked was manipulated prior to performing an immediate retention test. The control group performed only 18 red movement patterns right before the immediate retention test, and another group performed all movement patterns, however the 18 red movement patterns were performed right before an immediate retention test. Results from that study demonstrated both these groups to have improved movement time scores for immediate retention. Therefore, results from the current study can be explained by retroactive inhibition, or the improved retention of an activity due to the lack of interpolated activity between original learning and retention tests (Underwood, 1945). Another possible explanation suggests that subjects were able to “remember” the approximate movement times between each key, instead of “constructing” or learning them (Jacoby, 1978).

For the golf putting task, those practicing in a blocked practice condition demonstrated improved performance across trial blocks, as hypothesized. However there was not a significant difference between groups during acquisition or retention. This does not hold true for the hypothesis, stating that by increasing the amount of interference by having two distances and two different putting techniques would generate a contextual interference effect. However, this is in agreement with previous research failing to demonstrate retention benefits for random practice in complex domains (Bortoli, et al., 1992; Brady, 1997; Jones & French, 2006; Meira, & Tani, 2001). Researchers have attempted to offer explanations of why this holds true. One includes failure to learn the information when too much explicit knowledge is presented (Liao & Masters, 2001). For example, a novice might need to get a feel of basic movements before practicing under such high interference. Hebert (1996) demonstrates support for this for novice tennis players who actually increased scores during retention in a blocked practice condition. These individuals were able to retain the information more by practicing the skill repeatedly, getting a feel of the movement. Porter and Magill (2005) offer more insight to this by introducing the concept of increasing the amount of interference during the acquisition process. In their golf putting task, subjects completed a total of 81 putts. Of these 81 putts, the increasing interference group practiced the first 27 putts in a blocked practice condition (getting a feel for the movements), the second 27 putts in a serial order, and the last 27 putts in a random order (Porter & Magill, 2005). Significant differences were found for the increasing interference group compared to the blocked and random groups, but not between the random and blocked groups.

Brady (2004) summarizes the research for the contextual interference effect and demonstrates that for "applied" (e.g., complex) tasks, the average effect size was 0.19

(Cohen's *d*). Why is it so difficult to see this effect in applied research? Particular studies demonstrating the contextual interference effect use children as their subjects in complex tasks of a forehand tennis ground stroke and a soccer dribbling and kicking task (Farrow & Maschette, 1997; Vera, Barbero, Alvarez, & Montilla Medina, 2008). Both of these studies demonstrate support for blocked practice, or a combination of blocked practice and alternating practice, to be beneficial during the learning process. This is also in agreement with previous research (Hebert, et al., 1996). This exposes two theories. One, complex tasks might be too difficult to demonstrate random practice to be more beneficial when learning a new skill. The large explicit knowledge presented might generate too much interference (Liao & Masters, 2002); therefore, retention benefits will not be observed for random practice. Two, in order to generalize what is known from lab settings (in this case; random practice aides in retention of a skill), there needs to be as much external validity as possible. In order to reach an expert level, an individual must participate in deliberate practice, which states that in order to reach an expert level one must be fully engaged during practice and that it should not be enjoyable (Ericcson, Krampe, & Teschromer, 1993). With deliberate practice comes motivation to improve, specifically, intrinsic motivation (Pedersen, 2002). Children are more intrinsically motivated (Ward, Wilkinson, Graser, & Prusak, 2008), which might explain why such strong contextual interference effects were demonstrated for the studies mentioned above. Brady (2004) demonstrates the contextual interference effect to be stronger in adults (d=0.50) than children (d=0.09). However, this is comparing 80 effect sizes for adults compared to 18 effect sizes for children.

Attention. The role of attention, especially novice and expert differences, has been well addressed in the literature. Two specific methodologies include a secondary tone discriminating task (Beilock et al., 2000, 2002; Gray, 2004), and verbal instructions on focusing internally or externally (Wulf et al., 1993, 1998; Poolton et al., 2006). Beilock (2002) demonstrates an advantage for novices in a skill-focus group (e.g., distraction toward skill movement) while Wulf (1998) demonstrates an advantage for providing external instructions of attention (e.g., away from skill movement) for novices.

The present study demonstrates confounding results in reference to attention for both the discrete key pressing task and the complex golf putting task, supporting both hypotheses. To our knowledge, no study has observed attentional focus using skill-focus and extraneous-focus conditions in a discrete key pressing task. Results from the present study did not support the hypothesis that extraneous focus would increase performance during the acquisition phase, and instead demonstrated no differences between groups. However, results do support the hypothesis for delayed retention in the fact that those practicing with extraneous-focus promoted decreased constant and variable error scores. This has been demonstrated in previous work stating the benefits of directing attention away from skill movement in complex tasks (Wulf et al., 1998), and supports the hypothesis that efferent information presented from the tone for extraneous focus was more compatible to the skill movement. As a result, subjects were able to respond to the tone and shift attention back to the primary task more efficiently than the skill focus group.

The attentional capacity for an individual is limited, and when there is detrimental performance on the primary task of interest, this demonstrates interference from the secondary task. As reported by subjects, the key pressing task was considered more cognitively demanding (84%) compared to the golf putting task (16%). This cognitively demanding task required greater attentional resources for the primary task of interest. Allocation of the secondary task disrupted attention to the primary task of interest. Subjects in the skill-focus group experienced the afferent information to be incompatible with the skill movement, disrupting the learning process, causing a greater load on working memory (Maxwell, et al., 2000). Those with extraneous focus were able to maintain performance for the primary task despite the disruption from the secondary task, and demonstrate superior scores for constant and variable error as a combination.

For the golf putting task, those practicing in the skill focus and extraneous focus conditions improved performance during the acquisition period, and there was no difference between these groups. This does not support the hypothesis, expecting extraneous focus to have increased putting performance during acquisition. However only 16% of subjects reported the golf putting task to be more cognitively demanding compared to the key pressing task. Therefore, attention to the secondary task might not have affected performance for the primary task of interest as much as was observed in the key pressing task. Poolton (2006) demonstrated similar findings, in that both groups practicing under external and internal focus improved performance across trial blocks. This is contrary to other research (Beilock et al., 2002; Wulf et al., 1998).

Wulf (1998; 2007) demonstrates external focus to be beneficial for novices; however manipulation checks are not included in order to observe if an expert or novice is actually focusing their attention to where they were instructed to. As Gray mentions (2004), why would an expert who already has a planned movement upon execution of a well learned skill, focus on something they don't normally focus on? According to the constrained attunement hypothesis (Vicente & Wang, 1998), internal focus disrupts skill movement for an expert. But for a novice learning a new skill, this is debatable. Research giving instructions to focus externally or internally would benefit by giving verbal reports to participants to observe where the focus of attention was. In their experiment, Poolton (2006) observed novice golfers whose task was to putt as accurately as possible to a specific target. The experimenters gave (depending on what group) instructions to focus internally or externally. In addition, they conducted verbal reports to observe where subjects were actually focusing their attention. It was demonstrated that those practicing with internal focus instructions were able to process a greater amount of internally referenced explicit information while putting. In other words, they were able to generate more internal rules than the external focus group (Poolton, Maxwell, Masters, & Raab, 2006). Therefore, instructing novice participants to focus internally did not degrade performance and were able to recall the internal rules. This study demonstrates that focusing internally is not necessarily disruptive for a novice learning a new skill. In addition, the results also suggest that those practicing with internal focus (e.g., the skill focus group) were able to use internal information while putting in order to increase in their putting performance scores and that it was not detrimental to performance. Our study demonstrates this for the golf putting task, in that both groups with extraneous focus and skill focus were able to improve performance across trials.

Beilock (2000) utilized the secondary task probe technique for skill-focus and extraneous-focus conditions. The extraneous-focus group indicated if a tone was “high” or “low” while the skill-focus group said “stop” at the end of the putt. The choice-response was not equal between groups giving an advantage to those practicing in the skill-focus group. Results indicated novices in the skill focus group to have superior scores compared to novices practicing in the extraneous focus group. To equal the number of choice-responses, Beilock and Gray (2012) had novice and experts indicate the direction of the swing (forward or backward) for the skill-focus group, or identify a high or low tone for the extraneous-focus group. Results demonstrated expert and novice differences, and replicated the finding that novices in the skill-focus group had superior performance compared to the extraneous-focus condition. However, Poolton (2006) used a secondary task monitoring tone, and novices in both the skill focus and extraneous focus groups were similar in identifying the tone, and it did not account for performance differences (Poolton, et al., 2006).

One argument with using the probe technique methodology includes the level of difficulty for identifying the number of tones. Gray (2000) suggested that two choices were too simple of a task. Suss and Ward (2010) used the same probe technique in order to assess choking under pressure between novice and experts in a rifle-shooting task. The unique contribution from this study included participants having to respond to three tones (high, medium, or low) instead of two (Beilock & Gray, 2012). In their second experiment, participants in the skill-focus group were required to indicate what direction the finger was moving when shooting a rifle when a random tone was heard (by indicating if the finger was on, off, or out), while the extraneous focus group had to indicate whether the tone was high, low, or medium (Suss & Ward, 2010). Results from that study indicated no differences for the secondary task between the groups, and that performance was actually similar for extraneous and skill-focus conditions for novices. This is in agreement with results from the present study, which demonstrates no differences between groups for attention conditions.

Attention and Practice as an interaction. To our knowledge, literature is inconclusive in regards to optimal practice conditions (specifically random and blocked practice) and attention (inward/outward focus) as an interaction. In sport, changing the structure of the practice and cueing of attention for a novice can enhance the learning process and retention of a skill. To this point, it has been made evident to some degree the benefits of increasing interference during the learning process. To what degree this interference is might depend largely on the task. But does attention, in addition to practice, change the amount of interference during the learning process? To our knowledge, there is little research on how attention influences practice schedules. Literature demonstrates to some extent, the benefits of increased interference during practice to be better for retention. For attention, Beilock and colleagues (2000; 2002) demonstrate novices to have increased performance in a skill-focus condition compared to an extraneous-focus condition during the acquisition phase; however it is unclear how this affects performance on a retention test. Wulf and colleagues (1998, 2002) demonstrate external focus to be beneficial during both acquisition and retention, however verbal reports are not given in order to assess where attention is actually focused. Poolton (2006) demonstrated no differences between attention groups, and found that internal focus was not detrimental to performance. The inconclusive agreement for attention, and lack of research for attention and practice as an interaction, is an opportunity to gain insight as to proper attentional cueing techniques and appropriate practice schedules when learning a new skill. Additionally, this encourages interpretation on what combination is most effective for learning.

As hypothesized, results from the present study for the key pressing task demonstrate an advantage to those practicing in a blocked practice condition with extraneous focus compared to all other groups. This has been previously demonstrated for practice independently in discrete tasks (Shea & Morgan, 1979; Lee & Magill, 1986; Wright, et al., 2005) and attention independently (Wulf et al., 1998). Therefore, as a combination the blocked and extraneous focus group displayed superior performance compared to all other groups during the acquisition phase. For immediate retention, those practicing with extraneous focus in the blocked practice condition demonstrated decreased relative timing error. In addition, the same group demonstrated decreased constant and variable error for delayed retention. This was not hypothesized, as it was expected there would be a contextual interference effect.

The interpretation of these results as a combination deals with the amount of interference. If we look at interference on a continuum, it is essentially comparable to the inverted U hypothesis of arousal (Neiss, 1988). If an individual is over aroused, optimal performance will not be met. In reverse, too little arousal will also inhibit optimal performance. For interference generated, too much interference will disrupt the learning process (e.g., random), while too little interference does the same (e.g., blocked). The idea that too much interference may disrupt the learning process is supported by a study observing participants learn volleyball technical skills (Bortoli, et al., 1992). These subjects either practiced in a blocked, serial, random, or serial with high interference practice condition. Those who practiced in the random group and serial groups demonstrated superior scores on a transfer test, suggesting the interference was appropriate for learning. Those practicing in a blocked practice condition had too low of interference, while those practicing in the serial with high interference group experienced too much interference. Battig (1979) originally stated in order to increase interference during the acquisition process, task similarity needs to be increased, or one should practice randomly. Magill and Hall (1990) argued the opposite stating that to increase interference, task similarity should be decreased, and in order to do this the motor program should be manipulated. For the present study, interference was generated by practicing randomly, in addition to changing the motor program that included the distance (force) of the putt, the muscles used for each putting technique, and the relative timing between movement patterns. However, it is important to consider how attention affected interference as well. Beilock and Gray (2012) demonstrated skill-focus conditions to not disrupt performance for novices compared extraneous focus conditions. Therefore, interference was generated for novices practicing in the extraneous focus conditions as oppose to the skill focus conditions. For practice, Shea and Morgan (1979) demonstrate that by practicing in a blocked practice condition, no interference is generated compared to those who experience interference by practicing randomly. Therefore, as a combination for attention and practice, the greatest amount of interference is generated from extraneous focus and random practice. As a pair interference is then generated from one condition (blocked=no interference, random=interference, extraneous focus=interference, skill focus=no interference).

When combining conditions, blocked practice and extraneous focus, in addition to random practice with skill focus, experience appropriate interference. Results from the present study support this and demonstrate superior retention compared to blocked practice and skill focus (too little interference), and random practice and extraneous focus (too much interference). In other words, the combination of two different factors (practice and attention) generated interference for learning the task. Combining low interference from practice conditions (blocked practice) with high interference from attention conditions (extraneous) promoted increased learning. Likewise, combing high interference from practice (random) with low interference for attention (skill focus) also increased retention of the skill. Compared to the random practice with extraneous focus, too much interference was generated from practice (random) and attention (extraneous) during acquisition, therefore the learning process was disrupted. Those practicing in the blocked practice and skill-focus condition experienced no interference; therefore displayed inferior performance.

This theory also explains results obtained from the golf putting task. Though retention data did not demonstrate differences between groups, looking at figure 3.4 (in addition to posttest scores) there demonstrates a learning curve for both the random group in the skill-focus condition, and blocked group in the extraneous-focus condition. This is also demonstrated for the interaction between practice and attention. Looking at posttest scores compared to pretest scores, random practice (interference) and skill focus (no interference) demonstrated improvement in both putting techniques from each distance, while blocked practice (no interference) and extraneous focus (interference) demonstrated improvement in the long putt technique from both distances. In addition, because the cognitive demands for the golf putting task were not as high as for the key pressing task (16% compared to 84% for the key pressing), the increase of interference from both practice (random) and attention (extraneous) improved performance for the belly putt technique and long putt technique from the short distance. The interference was still appropriate for subject’s to perform the task.

Conclusion

In sum, practice and attention both contribute to the learning process. Interference to some extent engages an increased thought process between trials. Attention perhaps can be a contributor to the interference, by disrupting or promoting the learning process. Implications from the present study suggest that having novices practice in a blocked practice condition, getting a feel for the movement, yet generating interference by directing attention away from actual skill movement, can aid the learning process. Of course, this is dependent upon the task, which is apparent in the literature on the contextual interference effect for practice independent of attention. This can be demonstrated in the results from the golf putting task that was considered less cognitively demanding. The increased interference from both the random practice and extraneous focus did not disrupt the learning process, which was demonstrated on posttest scores.

Future research conducted in the two paradigms of practice and attention should consider motivation as a key aspect for external validity in complex tasks such as sport. In the present literature review of contextual interference for complex tasks, four studies gave course credit to participants while none provided an incentive (e.g., money). For attention using the probe technique methodology, an alternative implication for the extraneous-focus group would be, like the skill-focused group, to direct attention specifically to something in the environment as oppose to identifying the sound of a tone (e.g., the ball lands “on”, “far”, or “short” of the target).

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