

AN EXAMINATION OF THE IMPACT OF INTRODUCING GREATER
CONTEXTUAL INTERFERENCE DURING PRACTICE ON LEARNING TO GOLF
PUTT

A Record of Study

by

GYU-YOUNG HWANG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF EDUCATION

December 2003

Major Subject: Physical Education

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ABSTRACT

An Examination of the Impact of Introducing Greater Contextual Interference During
Practice on Learning to Golf Putt. (December 2003)

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The skill of putting in golf contributes approximately 40 percent to one's total score making it an important skill to master in golf. One of the critical means of improving putting skill is through practice. The purpose of this study was to: (a) investigate if different practice schedules with different degrees of contextual interference (CI) influenced the participants' immediate and long-term putting performance, (b) examine if performance changes were associated with concomitant changes in specific kinematic parameters, and (c) assess the cognitions of the participants during various stages of the practice of the putting skill.

Twenty-four undergraduate students were randomly assigned to either a blocked or random practice schedule. On Day One each participant practiced putting to three targets (4 ft, 8 ft, and 12 ft distance) for a total of 108 trials (36 trials to each target). On Day Two 30 trials of retention (10 trials to each target) and 10 transfer trials (10 ft distance) were performed. To obtain a kinematic description of the putting action, an OPTOTRAK™ 3020 camera system recorded the 3D movement of the putter. Participants' cognitions were analyzed from stimulated recall interview data.

Random practice participants exhibited poorer putting performance during acquisition compared to their blocked practice counterparts but showed superior performance in retention and transfer tests. While the blocked practice participants had significantly lower variability in the amplitude in the x -dimension for backswing, impact velocity, and putter position at impact (z -dimension) during practice, the random practice participants showed significantly lower variability in the amplitude of the x -dimension for the backswing and downswing, impact velocity, and putter position at impact during the retention and transfer phases.

Content analysis of interview data yielded three emergent categories: participant focus, self-evaluation of performance, and benefits of practice. The participants provided evidence of active thought processes during the putting task while receiving little instruction. The blocked group focused more on accuracy while the random group was more focused on judging distance. The lack of recognition about the z -dimension has potential implications for how instruction and feedback might be employed during the learning process.

DEDICATION

This educational endeavor is dedicated to the fondest memory of Yeon-Ha Hwang, my blessed father (February 24, 1925 to March 6, 1995).

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I wish to express my sincere gratitude to the members of my committee, Dr. Ron McBride as Chair, Dr. David Wright, Dr. Stephanie Knight, and Dr. Ping Xiang. Particularly, I would like to extend my special word of thanks to Dr. David Wright for guiding me through all of our experiments and for helping write this study.

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To my lovely son, Stephen Jeongho Hwang, thank you for your patience and encouragement. I hope you become a good man. You are always with me in my heart wherever I go.

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CHAPTER I

INTRODUCTION

This chapter reviews the literature on the contextual interference effect in motor skill learning. Two dominant contextual interference theories as well as applied research of contextual interference effects are discussed as are the kinematics of golf putting and stimulated recall interviews. Process tracing techniques used to gather cognitive data are also presented. Finally the delimitations and limitations of this study are summarized.

Contextual Interference (CI) in Motor Skill Learning

Battig (1966) first identified contradictory results from early studies of interference effects during the acquisition, retention, and transfer of paired-association in the verbal domain. Battig stated that high levels of intra-task interference produced inferior performance during the acquisition. During retention and transfer trials however, he found that the intra-task interference led to superior retention and seemed to produce positive transfer compared to low levels of intra-task interference. In Battig's follow-up study (1972) he introduced the term "contextual interference" and suggested that increased contextual interference leads to the use of multiple and variable processing strategies during learning. Battig concluded that practice under increased contextual interference could produce more elaborate and distinctive processing of the material to be learned and, therefore, would facilitate delayed retention and transfer.

This record of study follows the style and format of *Research Quarterly for Exercise and Sport*.

Shea and Morgan (1979) investigated the contextual interference phenomenon in the motor domain. Participants learned three motor tasks (three-segment patterns), each of which required rapid arm movements. Participants were instructed to knock down a specified sequence of barriers in a prescribed order. They were assigned to either a blocked group (low CI) or a random group (high CI). The participants in the blocked schedule completed all 18 trials of one practice movement pattern before repeating the same amount of trials for the next sequence of patterns. In the random schedule, participants practiced the three movement patterns in an indiscriminate order, 18 trials of each movement three times for a total of 54 trials. Both random and blocked groups engaged in the same amount of practice with the three patterns and were distinguishable only by the practice schedules.

Retention and transfer tests were administered to all participants after a 10-minute and a 10-day delay period following the 54 practice trials in the acquisition phase. Retention trials were performed in either a random or a blocked sequence. Half of the 18 trials involved a blocked schedule (3 trials per block) of the three practiced patterns and half involved a random sequence of the three patterns practiced. Participants also performed a transfer test that had two new movement patterns. Of the two transfer tests, one was considered more difficult and the other less difficult than the original movement patterns. The results indicated that during the acquisition period, the blocked group performed faster than the random group in reaction time, movement time, and total time. The random group, however, demonstrated superior retention on both transfer task performances than the blocked group.

The Bassin Anticipation Timer method was used to investigate the CI effect (Del Rey, 1982, 1989; Del Rey, Wughalter, & Whitehurst, 1982; Del Rey, Wughalter, Whitehurst, & Barnwell, 1983; Del Rey, Wughalter, & Barnwell, 1987; Edwards, Elliott, & Lee, 1986) in a series of studies. Del Rey et al. (1982) investigated Battig's CI effect (1979) using a coincidence anticipation task for participants with varied experience in open sport skills. Participants were required to make a key pressing response that coincided with the arrival of a light stimulus. Sixty experienced and novice females practiced responding to four different velocities in either a blocked, random, or constant practice schedule. Results indicated that the experienced participants exposed to random practice (high CI) performed better than the novice participants in the same acquisition context and acquisition under high CI facilitated transfer to a novel task. The generalizability of the results extended only to the faster of the two transfer speeds tested.

Lee and Magill (1983) conducted a series of experiments examining the locus of the CI effect in motor skill learning. Their experiment identified the problem found in the Shea and Morgan (1979) study. Lee and Magill (1983) used a cueing technique that indicated the task to be performed on the subsequent trial. Retention data for the experiment indicated that the cueing technique reduced reaction time for the random group, but did not account for the CI effect.

A serial group was added in experiment two to the random and blocked acquisition practice schedules. In the serial group, the same three tasks were practiced in a predictable sequence throughout acquisition. This serial group was included to address the effect of event unpredictability or non-repetition as the locus of the CI effect. Lee

and Magill (1983) hypothesized that if unpredictability of events is the key contribution to creating CI, the serial group performance should parallel that of the blocked group. If the serial group performance paralleled the random group, however, the effect of contextual interference could be attributed to the non-repetitive nature of the practice schedule. No differences were found between the random and serial groups in either acquisition or retention performance. Supporting the CI effect, the blocked group exhibited superior performance in acquisition compared to the random and serial groups but demonstrated significantly inferior performance for retention.

Lee and Magill (1983) suggested that since the primary methodological similarities between the random and the serial practice schedules lay in the order that events were practiced, the methodological locus of the contextual interference effect would seem to center in the non repetitive nature of the practice schedule. In addition to the retention trials, Lee and Magill (1983) administered a written recall test to evaluate participant memory for the movement task. Statistical analysis of this written test failed to indicate any significant differences between the acquisition groups. They concluded that results from experiments one and two demonstrated that non repetitive practice schedules enhanced the accessibility and implementation of suitable action responses compared to repetitive practice schedules.

In an attempt to examine the role of cognition in the production of the CI effect, Lee (1985) studied the effects of blocked, random and serial acquisition schedules on retention of prototype formations of geometric movement patterns. In order to test the emphasis on cognitive effects, Lee (1985) restricted participant plan-of-action and use-

of-error information through experimenter-constrained arm movements for eight different geometric figures. Based on the presumption that the advantage on retention and transfer for random and serial conditions was attributable to cognitive analyses in action planning and error processing information, Lee (1985) expected to see little or no benefit for random and serial over blocked presentations. Obtained results from the experiment confirmed that retention and transfer judgments for experimenter-constrained movement patterns were not influenced by the type of presentation schedule engaged during acquisition trials. Lee suggested that the differences produced from the practice order in previous experiments might be attributed to elevated planning and processing of error feedback afforded through random and serial practice schedules (Lee, 1985).

In summary, the contextual interference effect in motor skill learning represents a topic of importance in the motor learning literature. It is also important to consider current theoretical frameworks that have been offered to account for the CI effect in the motor domain. Once these hypotheses are understood, it should be possible to design learning situations that encourage students' learning and therefore optimize the retention of learned skills. Two primary theoretical hypotheses attempt to explain CI effects: the elaboration hypothesis and the reconstruction hypothesis.

The Elaboration Hypothesis

Based on upon Battig's original work, Shea and Zimny (1983) proposed that multiple skills learned under conditions of high CI are encoded more elaborately and distinctively. This elaboration and distinctiveness results from multiple and variable

encoding processes. Multiple encoding processes refer to the number of different strategies employed by the learner, while variable processes refer to the different times at which these different strategies are employed. A high CI (random) practice schedule is believed to allow the representations of tasks (such as a perceptual blueprint) to reside together in the working memory. As a result, there is greater opportunity for inter-item processing where comparisons are made among tasks. These comparisons typically focus on features of a task that are common to other tasks.

This type of processing leads to the storage of quantitatively more elaborate task related information because specific information is encoded about a particular task and additional information is encoded and organized based on the relationships among tasks. Elaboration is not only confined to the amount of information encoded about a task, it also relates to the number of different strategies used to encode this information. The unsystematic variation afforded by a random schedule is thought to encourage the use of several encoding strategies because tasks are repeatedly encountered in different contexts.

Both elaborative and distinctive processing decrease the dependence of memory on the reinstatement of the original encoding context. This results from the use of different encoding strategies as well as the storage of a number of contextual components – each of which can serve as a potential cue to retrieve a task from memory. Furthermore, transfer performance will be facilitated because this type of processing is thought to make retrieval of tasks from memory a more flexible operation and is not constrained by a particular context.

A low CI (blocked) practice schedule does not provide the same opportunities for elaborative and distinctive processing as a high CI (random) schedule because inter-item comparisons cannot be made among tasks. Instead, the blocked schedule encourages intra-item processing. Intra-item processing refers to processing that focuses on the individual components and characteristics of a particular task independent of the other tasks. Intra-item processing does not facilitate retrieval of task related information from memory, but it does allow a task to be distinguished or recognized from a number of other tasks. Therefore, blocked practice participants usually display superior performance during practice but perform less well than the random practice individuals at the time of retention. The poorer acquisition performance of the random practice participants is associated with greater demand on the attention resources in the practice phase than experienced under blocked practice (Li & Wright, 2000).

Li and Wright (2000) hypothesized that random practice requires additional cognitive activity. If this is the case, one should be able to demonstrate that random practice places a greater demand on the attention resources available to the learner in the practice phase than does blocked practice. Another consideration is the temporal locus of the differential attention demand during random and blocked practice schemes. Reconstructive activity would not take place until the learner receives the necessary information about what plan needs to be constructed. The interval immediately after being informed of the impending response should incur larger attention costs for the random participant compared to the blocked participant.

The tasks in Li and Wright's (2000) experiment required pressing three 4-key-press sequences with a distinct segmental timing requirement and a Choice Reaction Time (CRT) task (high and low tone). Eighty-four participants were randomly assigned to one of six practice conditions: random/alone (R/A), blocked/alone (B/A), random/pre-response interval (R/PR), blocked/dual/pre-response interval (B/PR), random/dual/inter-trial interval (R/ITI), and blocked/dual/inter-trial interval (B/ITI). The data revealed a typical CI effect for the primary key-pressing task. Blocked-practice participants displayed superior performance during practice but performed less well than the random-practice individuals at the time of retention. The poorer acquisition performance of the random practice participants was associated with higher cognitive demands during both the pre-response and the inter-trial intervals than that of individuals assigned to blocked practice. Li and Wright (2000) explained that the random practice participants exhibited a 20% greater secondary CRT than did their blocked practice counterparts. Thus, the planning operations used by the random practice participants did appear to be more demanding than those used by participants exposed to the blocked practice schedule.

Wright (1989) used a different approach to examine the elaboration view. In an attempt to find empirical support, he manipulated the amount of intra-task and inter-task processing performed by participants during practice. Using a barrier knockdown task, he contrasted one random condition with four blocked conditions. The blocked conditions were differentiated by the additional intra- or inter-task processing (i.e., processing directed specifically toward the task itself or processing which incorporated between-task comparisons, respectively) introduced between trials on the tasks. Results

indicated that the random group and the blocked group with additional inter-task processing (i.e., participants were asked to identify similarities between tasks) were superior in their retention and recall compared to the other groups. The performance of the blocked group, supplemented with additional inter-task processing, performed similarly to the other blocked conditions during acquisition which were, in turn, significantly better than the random condition. This suggests that superior retention performance does not have to occur at the expense of degraded acquisition performance created by a random practice schedule. The provision of additional intra-task processing provided some benefit for recall (in this case recall did not require performance of the task), but did little to improve retention performance. These results provide strong support for the elaboration explanation for the CI effect in motor skill learning.

The Reconstruction Hypothesis

Another explanation for the CI effect comes from Lee and Magill (1985). They were not satisfied with the elaboration hypothesis because the concepts of “elaborateness” and “distinctiveness” were abstract and difficult to define. Furthermore, the explanation did not account for the inferior performance of the random group during acquisition. They felt the type of processing undertaken should have been beneficial, rather than detrimental to this stage of practice. According to this account for the CI effect, Lee and Magill proposed that in a random practice schedule, an action plan utilized on a previous trial is forgotten as a result of intervening trials on other tasks. Processing information about a particular skill in a random condition is more effortful because previously encoded information about that skill has been partially or totally

forgotten and must be reconstructed on subsequent responses (Immink & Wright, 1998; Immink & Wright, 2001). This leads to a stronger memorial representation of the skill resulting in enhanced learning. Transfer is also facilitated as performance on a novel task requires new action plans to be constructed. However, under a blocked schedule, the learner has little opportunity to forget because the action plan resides in working memory and can be reenacted on successive attempts with little reconstructive activity. The basic premise of this hypothesis is that the action plan is remembered under blocked practice and reconstructed under a random schedule.

Weeks, Lee, and Elliot (1987) attempted to manipulate the degree of initial forgetting between presentations of bi-directional arm movements performed at either fast, slow, or medium speeds. Participants self-selected either a fast, slow, or medium criterion movement and attempted to produce and reproduce a given movement immediately after a 20 second unfilled interval, after a 20 second interval filled with an “easy” cognitive task (counting backwards by 3’s), or after a 20 second interval filled with a “difficult” cognitive task (counting backwards by 7’s). After the reproduction, a recall attempt followed a 20 second filled (easy) retention interval. Results indicated superiority for the “filled difficult” conditions indicated by lower variable and absolute constant error. Weeks et al. (1987) concluded that superior retention resulted from reconstruction of the action plan that had been purged from memory after the initial production attempt. This conclusion appears warranted because the difficult task should result in more forgetting between presentations of the movements that would then have necessitated greater reconstruction.

Immink and Wright (1998) studied the reconstruction hypothesis as to whether or not random practice promoted greater reconstructive processing (i.e., movement time) than blocked practice. If yes, the time period within which these processes occurred (i.e. study time) should be greater. The reconstruction position stresses the cognitive procedures occurring between the imperative signal and the initiation of a movement. More specifically, action plan reconstruction can proceed only after the participant becomes aware of the movement for which the plan must be constructed. It is the demands of the intra-trial processes within particular practice schedules that are central to the reconstruction position that is the focus of Immink and Wright's work.

Their findings from Experiment One (four pressing keys – A, S, D, and F) agreed with the prediction that random practice participants spent more time planning a movement during acquisition than blocked practice participants. Experiment Two (END key used) generally confirmed the results obtained in Experiment one. In Experiment Three, study time (ST) was fixed with either one or two seconds. It was assumed that reducing the amount of ST from two to one second for individuals trained under a random schedule would limit the amount of planning that could be conducted when preparing for an upcoming response. It was also predicted that these individuals would need to entertain additional planning activity in one or possibly both of the intervals defined as Reaction Time (RT) and Movement Time (MT) compared to the performers afforded sufficient time (two seconds) to pre-plan the upcoming movement. In contrast, blocked practice participants were expected to exhibit similar MTs, regardless of the ST

condition. This is supported by the fact that MT increased for the random practice condition as study time was reduced.

In sum, each theoretical hypothesis produces empirical evidence supporting its position. The elaboration hypothesis accounts for two qualitatively different categories of information processing activity that the performer can engage during practice (Shea & Zimny, 1983). According to the reconstruction hypothesis, action plans for a particular task are forgotten—purged by intervening trials under a random practice schedule (Brady, 1998). The learner is forced to engage in more effortful reconstructive processing to regenerate the action plan for subsequent performances.

The next section reviews CI application to practical settings. Findings of practical setting studies varied according to the task variation in confirming the CI effect.

Applied Research of CI Effects

Goode and Magill (1986) attempted to apply CI effects to real world settings in their study with novice badminton players. The players practiced the short, the long and drive serves three days a week for three weeks in either a random, blocked, or serial practice sequence. Goode and Magill hypothesized that if the CI effect is generalizable to the teaching of a sport skill, then random and serial practice should lead to superior skill retention and transfer compared to blocked practice. Results indicated that random practice led to a better retention performance as well as to a better transfer performance when the same serves were executed to the unpracticed left side of the court. However, acquisition results revealed no significant differences among the groups.

Landin and Hebert (1997) applied the CI effect to a basketball shot. They selected six different positions of the court that varied in angle and distance from the basket and let participants (N = 30) practice an assigned schedule: low, medium, and high CI for 30 trials (5 from each position) per day for three days. Participants from the low CI group performed six successive trials from each position. Those assigned to the medium group performed three successive trials at each position and repeated the sequence twice. The high CI group practiced one trial per position in a serial arrangement and repeated the sequence six times. On Day Five, the retention test was administered with a 12-trial blocked test, a 12-trial serial test, and a 10-trial free throw test performed in 2-trial sequences separated by brief intervals. Results indicated no significant differences among groups during practice. The moderate CI group, however, performed significantly better than the other groups in the retention test. These findings were somewhat contrary to laboratory based results. The authors explained that laboratories provide environments where all possible confounding variables can be controlled. Results may differ in a practical setting where a myriad of factors influencing participants occur freely and interact differently from one task to another.

In a study incorporating volleyball skills, Bortoli, Robazza, Durigon, and Carra (1992) examined the effects of different practice schedules on learning the bump, the two-handed volley, and the underhand serve. Fifty-two ninth-graders were randomly assigned to one of four practice conditions: blocked, random, serial, and serial with high contextual interference. The blocked and serial with high interference represented the lowest and highest interference levels, while the serial and random group represented

intermediate levels. Participants performed 72 trials of each skill over six days. At the conclusion of the study significant differences were obtained only for the serve. The random and serial groups (moderate interference) were superior to the other two groups on the serve. Bortoli et al. (1992) suggested that the groups' lack of significant differences on retention may have related to the characteristics of the skill being tested. Perhaps the short duration of the study and skill difficulty precluded more robust effects. The authors noted that learning, though very mechanical under a blocked schedule, impaired verifying, repairing, and adapting the skill to task demands on the next attempt under very high conditions of CI.

This explanation supports Pigott and Shapiro's (1984) conclusions about the generality of variability in practice with 64 seven- and eight-year-olds whose task involved tossing four different weighted bean bags at a fixed target. Participants were assigned to a random, random-blocked, or blocked group and performed 24 practice trials. The random group randomly switched weights from trial to trial. A random-blocked group practiced at one weight for three trials and then was randomly assigned to a different weight for the next three trials until the conclusion of the practice session. The blocked group practiced at each weight for six trials before switching to the next weight.

Upon the completion of practice, all participants immediately transferred to three test trials at either two ounce or seven ounce bean bags. The random group made the most errors (distances from the target), while the random-blocked group was noticeably better than others in the latter acquisition stages. The random-blocked group also

recorded superior performance at transfer to novel variations of the task. The authors concluded that given a short practice session, the random-blocked practice allowed the participants to reinforce a desired response and allowed for adaptation to several random changes before transfer.

Boyce and Del Rey (1990) randomly assigned 60 members of college rifle classes to a blocked or random practice schedule. Blocked instruction was administered to all participants before being assigned to a specific schedule. In this study, 20 acquisition trials were performed over a 4-day period. During acquisition, the blocked group performed with significantly greater accuracy than the random group but there were no significant differences in retention. However, in transfer, the random group was significantly more accurate. CI effects were found for acquisition and transfer. Boyce and Del Rey noted that their findings supported the progression from blocked practice to random. That is the novices benefited from beginning in a consistent environment (i.e., blocked practice) before practicing in a more variable one (i.e., random practice). The authors also noted that participants practicing under a random schedule had more opportunities to compare different targets by making postural adjustments. Such adjustments were beneficial when participants had to respond to a novel target location during transfer.

Wegman (1999) examined the effect of three practice methods (repetitions, random, and combined) on ball rolling, racket striking, and ball kicking. Participants were 54 fourth grades girls who participated in 39 trials (13 trials of each skill) according to their practice schedule. A retention test followed three weeks later with

five trials of each skill. Results showed a significant improvement for the three groups on all skills practiced. The repetition group was significantly better than the other two groups during practice. In the retention test, the random group performed significantly better than the other two groups in the racket-striking skill. The author stated that results were specific to the given population (girls in Grade four) and the tasks (fundamental motor skills).

Strong support for CI comes from Hall, Domingues, and Cavazos's (1994) study of skilled college baseball players where 30 players were randomly assigned to one of three practice groups: control, blocked, or random. The groups had two practice sessions per week for six weeks. Sessions consisted of 45 pitches: 15 fastballs, 15 curveballs, and 15 change-ups. On a transfer test, the random group improved 57%, the blocked group 25%, and the control group 6%. There was no significant difference between the random and the blocked groups in the acquisition phase. The authors deemed the findings noteworthy because most CI studies previously had not focused on highly skilled athletes. Hall et al. (1994) concluded that the CI effect could be very robust in applied settings.

In another study performed in an applied setting, Brady (1997) investigated whether blocked or random practice was more effective in teaching golf skills. Participants were 36 (22 men and 14 women) university undergraduates in a beginner's golf class. They practiced four golf skills (the drive, middle distance iron, pitch, and chip shots) under two conditions, blocked and random. On the first day of instruction, all participants practiced four skills in a blocked manner with 15 repetitions of each skill.

For the remaining 12 classes, the learners were divided into two practice groups: high and low interference. One week after the last day of class, participants played 18 holes. The dependent variable was the total number of shots required to hit the ball on to the green. No significant differences were found between the random group ($M = 79.2$ cm, $SD = 9.9$ cm) and the blocked group ($M = 80.7$ cm, $SD = 9.6$ cm). The author believed there may not have been enough trials to generate CI. Another possibility was practicing four skills may have introduced too much interference.

In a related golf-skill study, Guadagnoli, Holcomb, and Weber (1999) examined the effectiveness of two practice protocols (random and blocked) on learning the putt. Fifty-eight college students (30 males and 28 females) participated. Three different targets (6 ft, 10 ft, and 16 ft) were used and each was surrounded by five circles for scoring (the closer to the target, the higher the score). Based on a 12 putts in a random order re-test, participants were divided into two groups: experienced and novice. Each group was also divided into either a random or blocked practice schedule. In total, there were four groups: novice-blocked, novice-random, experienced-blocked, and experienced-random. Each participant putted 12 times to each target each day based on their practice schedule for four days. On Day Five, the identical post-test was administered.

Novice participants under the blocked protocol had a greater increase in performance on the retention test. The experienced participants under a random protocol, however, generated a greater increase in performance on the retention test. The authors concluded that the traditional putting practice technique (blocked) was more beneficial

for the novices, while the theory based practice technique (random) was more beneficial for the experienced participants. The authors suggested that an optimal practice schedule should consider the performer's level because learning efficiency is based on the learners' information processing ability. The random practice protocol may result in overloaded information to the novice making learning an inefficient process. When learners are more experienced, they can more efficiently handle a random practice protocol because they then have the ability to chunk information more efficiently. Thus, for the experienced learners, the random protocol may more efficiently promote the processes necessary for skill acquisition.

Although the results of studies conducted in practical settings varied, field-based research provides considerable support to the generalizability of the CI effect. Schmidt (1988) concluded, "Whatever the theoretical explanation for those curious effects, it is clear that they are present in both laboratory and practical settings, lead to relatively large differences in learning, and seem to represent stable and dependent principles of motor learning." (p. 399)

Kinematic Analyses in Golf Putting

Delay, Nougier, Orliaguet, and Coello (1997) compared experts and novices in a golf putting activity. Ten expert and 10 novice players putted to distances of 1, 2, 3, and 4 meters as accurately as possible. The expert players were either professionals or had a handicap less than five. The novice players had no golf experience. Movement of the club was recorded at 200 Hz via a SELSPOT system. Putting continued until the participants performed 10 successful trials to each distance. The investigators measured

backswing movement (BS) and downswing (DS) movement. The BS began at the starting position of the club next to the ball and was terminated at the highest point of the club when it was moved away from the ball. The DS began at the point the BS was completed and ended at the highest point of the putter after ball contact.

Results indicated that participants increased the force applied to the ball by increasing the amplitude of the impulse rather than increasing its duration. Delay et al. (1997) reported that the expert DS movement was longer and higher than the novice DS movement. The movement time of the experts was longer and the club velocity at impact was lower than the novices. A longer DS movement and a longer movement time accelerated the club and allowed a more precise impact with the ball. BS amplitude among the participants increased as the target distance increased. The experts, however, had a longer and lower BS movement as well as a longer BS movement time. BS movement time also increased as the distance to the target increased.

The authors stated that this isochrony principle facilitated programming of the movement regardless of the participants' level of expertise. In order to increase club velocity, the participants need to specify the amplitude of the BS movement, maintaining the shape of the movement and the DS movement time constant. The larger the amplitude of the BS, the larger the amplitude of the DS movement. As a result, the velocity of the club while traveling this larger DS amplitude within the same time was also higher. While both experts and novices demonstrated similar behaviors, the novices showed greater variability in amplitude of club movement and movement time.

Paradisis and Rees (2002) also examined parameters used by expert and novices with college level golfers. Eight college golf team members and eight recreational players who played on average once a week served as participants. Participants, however, only putt to an eight foot target. A 2D video analyses (50 Hz) established whether any differences existed between the experts and the novices.

Similar to Delay et al. (1997), results showed that the experts had a longer backswing movement and a lower head displacement. The novices showed greater variability in both backswing and downswing. However, there was no significant difference in downswing movement between two treatment groups. The authors also stated there were no significant differences on club velocity at impact between the two groups because they only analyzed the successful putts. Paradisis and Rees (2002) concluded that the novices had more variability in velocity at impact during their stroke. Unfortunately these studies (Delay et al., 1997; Paradisis & Rees, 2002) did not report putting performance and its relationship with these kinematic parameters. While one would assume the experts demonstrated greater putting accuracy it would be advantageous to directly map putting outcome to the specific kinematic characteristics of each putt.

While the above studies reported the overt performances of participants under various CI conditions, they do not account for the thought or decision-making process that may have guided their performance. Process tracing is a verbal report method that endeavors to obtain data on the “intellectual processes used by subjects as they render judgments and make decisions or solve problems” (Shulman & Elstein, 1975, p.4).

Process tracing has long been used in educational research to examine teacher planning and interactive thought processes (e.g., Clark & Peterson, 1986) as well as student thought processes (e.g., Wittrock, 1986) when examining the effects of teachers instruction on student learning and perceptions. In physical education researchers have used process tracing procedures to examine teacher planning (Housner & Griffey, 1985), assess student problem solving strategies (Bonette, McBride & Tolson, 2001), and as a strategy for gaining access to student meanings and interpretations constructed during motor skill performances (Langely, 1992; Shea & Zimny, 1983). Shea and Zimny (1988) concluded that such procedures provide "...a rich source of information to subject's processing activities..." (p. 304).

Stimulated Recall

Stimulated recall represents one process tracing procedure that produces a verbal protocol whereby an individual is asked to "think aloud" while viewing a videotape of him/herself performing a task. Bloom (1953) first used stimulated recall when he audiotaped lectures and used the tapes to stimulate student's recollection of what they had been thinking at the time. He stated that students' recall was 95% accurate when they heard the lecture material two days later.

Ericsson and Simon (1984) caution that stimulated recall procedures should be conducted as soon as possible after a task is completed because information established in long-term memory becomes not a direct report of the experience, but tends to become a combination of the experience and other related memories. The use of multimedia like

videotape in a recall session has the benefit of replaying and reintroducing the original cues present during the task in which the participant was engaged.

The videotape stimulates the participants' memory and helps them recall information in greater detail (Wittrock, 1986). By reviewing the tape, participants are able to recall in more detail what they were thinking and what they were trying to do at any given moment. Stimulated recall procedures can be used where a think aloud protocol would interfere with the performance of the task being examined. For example, teachers cannot teach and manage their classrooms while simultaneously reporting their thoughts on the activity taking place. Numerous studies in kinesiology have used stimulated recall techniques to examine critical thinking (McBride & Bonnette, 1995), student thought (Lee, Landin, & Carter, 1992), the acquisition of teacher knowledge (Schempp, 1995), classroom ecology (Supaporn, Dodds, & Griffin, 2003), and nurse education (Liimatainen, Poskiparta, Karhila, & Sjogren, 2001).

Lee et al. (1992) reported student thoughts during a tennis unit. Thirty fourth-grade students were taught the forehand and backhand strokes in two 30-minute lessons over two separate days. The first 15 minutes of each class entailed teacher instruction, while the last 15 minutes was for individual practice. Each student hit 20 practice balls while the teacher monitored and provided feedback if needed.

Instruction over the two days involved four phases: (1) verbal instruction, demonstration, and controlled practice of the grip and forehand drive; (2) individualized practice session with feedback; (3) review of technique followed by controlled practice; and (4) individualized practice session with feedback. The first two segments occurred

during day one and the remaining two segments followed on day two. During each lesson the students and the teacher were videotaped and stimulated recall interviews conducted upon completion. The tape was stopped at various points in the lesson and the students were asked what they were thinking about at that time.

Analyses of the interview data generated three emergent categories: (a) reports of affective thoughts, (b) reports of skill-related thoughts, and (c) reports of off-task thoughts. Affective thoughts were classified into three subcategories. These were negative evaluation (e.g., I didn't think I was doing it), motivating self (e.g., thinking about trying hard), and self-task assessment (e.g., thinking it would be easy). Reports of skill-related thoughts had two categories: skill outcome and skill technique. Skill outcome related to the task in general but not to any point in technique (e.g., thinking about playing tennis). Skill technique related to the critical elements of the skill (e.g., thinking about keeping my wrist right). Off-task thoughts were thoughts unrelated to the lessons (e.g., thinking about going home).

Lee et al. reported that the students recording more of the skill-related thoughts tended to perform better during individualized practice. Another finding was that affective thoughts were important mediators between instruction and quality of practice. For example, negative self-evaluation thoughts were negatively related to students' success. The authors concluded that interviewing students about their thought processes during instruction can provide teachers with information about what instructional stimuli students cue in on during practice.

Housner and Griffey (1985) used stimulated recall to investigate the differences in teaching planning between experienced and inexperienced teachers. Eight elementary physical education teachers with five or more years of teaching experience and eight preservice teachers served as participants. All teachers were videotaped on two 24-minute lessons about soccer and basketball dribbling to four children on two days. After viewing each of six segments of a lesson, the teachers were asked to respond to a set of questions: (1) What are you doing in this segment and why? (2) What were you noticing about the students? (3) Were you thinking of any alternative actions at that time? (4) Did anything you noticed during the lesson cause you to act differently than you had planned?

The results of this study indicated many differences between experienced and inexperienced teachers. When planning the lesson, experienced teachers made more decisions concerning strategies for implementing instructional activities than did inexperienced teachers. During interactive teaching, experienced teachers focused most of their attention on individual student performance while inexperienced teachers attended most frequently to the interest level of the entire class of students. The authors found that experienced teachers posed knowledge structures rich in strategies for managing students and facilitating psychomotor performance that enabled them to attend to individual student performance and alter their lessons in accordance to students need. In contrast, the inexperienced teachers possessed fewer of these strategies and focused their attention on the interest level of the entire class to insure that the students were busy, happy and well-behaved.

McBride and Bonnette (1995) examined how a teacher structured the learning environment to foster critical thinking with a group of at-risk students in a nontraditional classroom setting. The authors defined “at-risk” students as those learners who may forgo their education and drop out before graduating from high school. McBride and Bonnette (1995) used both quantitative and qualitative methods to collect data. The New Jersey Test of Reasoning Skills and the Teacher Observation Form – Critical Thinking (TOF-CT) were used for quantitative data and stimulated recall interviews were used to gather qualitative data. Forty-three students participated in an initiative games class and critical thinking three times a week for four weeks in addition to the camp’s regular activities, while 28 students participated in the regular camp activities only. Two observers videotaped and recorded teacher behaviors for a 40-minute initiative games class during weeks 2, 3, and 4. Following each lesson, two students participated in a stimulated recall interview and were asked three questions: (1) What was going on in this section?, (2) What were you thinking about at this point?, and (3) What did you notice about the other students? At the completion of the study, the investigators randomly selected one of the videotaped lessons for a stimulated recall interview with the instructor. The teacher interview followed the same format as the student interviews.

From the interview data, McBride and Bonnette (1995) reported that the teacher primarily focused on monitoring the learning environment. Responses included thinking about and describing student characteristics, noting levels of student participation and persistence, as well as observing student strategy formation and acknowledging their

thinking skills and teacher input. Results of the student interviews revealed thoughtful, reflective thinking and provided a notable affective component to the critical thinking process. The participants remained focused and motivated, persisted even when discouraged and provided evidence of critical thinking through strategy and plan formation. The authors concluded that the participants demonstrated evidence of active and self-regulated learners – all within an environment structured by the teacher.

More recently, Supaporn et al. (2003) examined how the classroom ecology and program of action influenced participants' understandings of misbehavior in a middle school physical education setting. The authors used Doyle's (1977) ecological paradigm as a theoretical framework. Inherent to this paradigm is the program of action (PoA) which is the simultaneous and ongoing interrelationships among the three major task systems composing the classroom ecology: the instructional, managerial, and student social task systems. One teacher and 14 students (5 eighth-graders and 9 seventh-graders) participated in a 10-day basketball unit. Each class session lasted 47 minutes and data were collected using stimulated recall interviews from four of the 10 videotaped classroom sessions. The 14 students and the teacher individually watched the four videotapes, then identified and described instances of misbehavior on the videotapes.

Supaporn et al. reported that most student misbehaviors were RRE-related (rules, routines, and expectations), primarily verbal or physical and were reported as interfering with instructional or managerial tasks. Verbal misbehaviors included talking, yelling, criticizing peers, using inappropriate language, or arguing with the teacher. Results indicated that the primary vector in the overall PoA of this class was more social than

academic. That is, the overall PoA was weaker in terms of learning and stronger as a primary social vector due to a lack of clearly defined classroom RREs. The teacher contributed to the primary social vector because of a lack of clarity in instructional tasks that resulted in continuous task negotiation with students, classroom interruptions that interfered with lesson flow and an overall looseness of accountability measures. Underneath the primary social vector for students was their desire to have fun; which they did in this class by talking, fooling around, and pursuing other interactive social agendas during lessons. The authors reported results similar to previous studies examining classroom ecology and program of action.

In summary, this chapter reviewed contextual interference effects in both basic and applied research. Two theoretical perspectives, the elaboration and the reconstruction models, were highlighted. Although each theoretical perspective produced empirical evidence supporting its position, there existed considerable commonality between them. The common denominator may be the enhanced cognitive activity engendered by random practice schedules and the deficient or decreased effortful processing resulting from blocked practice schedules. Process tracing techniques, specifically stimulated recall interviews were also discussed as a viable research strategy to acquire data on the cognitions used by learners as they make decisions and solve problems. Finally, the last section presented the delimitations and limitations of this study.

Delimitations

The study is delimited to:

1. Students enrolled in Kinesiology 406 (Motor Learning and Skill Performance) classes at Texas A&M University during the first summer semester of 2003 school year.
2. Novice golfers.
3. Group sizes of 12 students each ($N = 24$) randomly assigned one of two practice schedules
4. Only those participants providing written consent.
5. Practice schedules of 108 trials (36 trials to each target) and a retention test of 30 trials (10 trials to each target) after 24 hours. Also, a transfer test was delimited to 10 trials to a new 10 foot target after the retention test.

Limitations

Limitations to the following study include:

1. Some participants could not take the retention test after 24 hours due to conflicts in class schedules.
2. Different self-motivation and performance abilities may have been employed by the participants during the practice, retention, and transfer phases of the experiment.
3. The length of practice may affect participants' motivation and ability to attend to the experiment because of fatigue resulting from the frequency of trials involved.

4. The results of the experiment may be specific to the putting tasks of this sample population.
5. The artificial putting surface does not constitute a 'real life' putting green and may affect performance.

CHAPTER II

THE STUDY

Introduction

Golf is one of the fastest growing sports in the modern era with current approximations indicating in the order of 26.7 millions golfers across the United States. To acquire some competence in this arena, an individual must master a variety of movements that propel a ball accurately over a few hundred yards or just a few of inches. Putting, the skill that is performed when the golfer is close to the hole, contributes approximately 40 percent to one's total score (Gwyn & Patch, 1993) and would seem important to master if an individual wishes to attain some level of expertise (Paradisis & Rees, 2002).

Despite the importance of putting, few studies have actually examined the kinematics of this action and more importantly how such kinematic parameters change as the performer progresses from a novice to becoming skilled. It is important to understand that putting is unlike striking the ball over longer distances as might be the case when "driving." In the latter case the performer attempts to move the golf club to strike the ball with maximum club head velocity which constrains how the movement unfolds. In contrast, putting places fewer constraints on the player with regard to how the putter is moved in time and space. In other words, there are numerous combinations of movement time and putter amplitude that would achieve the necessary ball velocity and force to propel the ball towards the target. However, it is not unreasonable to

assume that there exist combinations of putter timing and movement extent that would result in more successful putting outcomes. If this is true, identifying these characteristics would be useful to both player and instructors alike.

One of the few systematic studies of the putting action was conducted by Delay, Nougier, Orliaguet, and Coello (1997). They described the action of putting as having two specific phases: the backswing (BS) and the downswing (DS). The BS begins at the starting position of the club next to the ball and is terminated at the highest point of the club when moved away from the ball. The DS begins at the point the BS was completed and ends at the highest point of the putter after ball contact. Delay et al. (1997) focused primarily on the amplitude and movement time of the BS and DS. They revealed that the amplitude of both the BS and DS components increased as the distance to the target increased. Moreover, increasing the distance to the target was not accompanied by a concomitant increase in the DS movement time. Rather the DS movement time was held constant. Thus, the strategy being adopted by these individuals to achieve greater putter velocity which was needed to move the ball over a larger distance was to adjust the amplitude over which the putter was displaced rather than change movement time.

Delay et al. and a more recent study by Paradisis & Rees (2002) also provided a limited examination of some of the kinematic characteristics of putting that distinguished expert and novice performance. In general, experts had longer and lower BS amplitude as well as longer and higher DS amplitude. Experts also had longer BS and DS movement time and lower velocity at impact. Longer DS movement and longer

movement time allows for the acceleration of the putter resulting in a more precise impact with the ball. Novices showed greater amplitude variability than experts. Unfortunately these studies did not report putting performance and its relationship with these kinematic parameters. While one would assume the experts demonstrated greater putting accuracy, it would be advantageous to directly map putting outcome to the specific kinematic characteristics of each putt.

In addition to the instructor knowing what the nature of the movement should entail (i.e., kinematics) in order to facilitate the performer's putting capability, one would also assume that they would be concerned with identifying and using practice procedures that might expedite the attainment of the desired kinematic characteristics. It is not uncommon for golf instructors to try to improve putting skills through the use of repetitive practice. The importance of using repetitive practice as a means of accomplishing skilled behavior has been the focus of numerous studies in recent years and addresses the role of contextual interference (CI) (Brady, 1998; Magill & Hall, 1990). CI refers to the degree of difficulty created in a practice session as a result of introducing practice on interpolated activity between repetitions of a particular task – where a task may be an independent skill or a variation of a particular skill

Typically, the extent of CI encountered by the learner during practice has been crafted by manipulating the arrangement of practice. Random practice is frequently used as a practice schedule that introduces high CI during a practice session. This practice format generally involves practicing multiple variations of a movement in a random order within a single bout of practice. In contrast, blocked practice proposes to create

relatively less interference because it consists of practicing the same movement repeatedly prior to the introduction of alternative movement variations that must subsequently be learned. There is a general observation that experiencing greater interference during acquisition (i.e., random practice) disrupts initial performance but enhances later retention and transfer efforts compared to the blocked practice format that creates little interference during the practice stage. In the perceptual-motor domain this finding is quite robust having been observed in a variety of laboratory and applied situations, among a variety of subject populations (Del Rey, Wughalter et al. 1982; Edwards et al. 1986), and in a number of different environmental settings (Goode & Magill 1986; Shea & Wright 1991).

Golf instructors consider blocked practice as the primary means of improving golf putting performance (Simek & O'Brien, 1994). Since putting is a skill requiring high concentration and confidence for success, it is thought that a blocked practice may develop confidence needed for successful performance. However, this approach is counter to the current information available about CI and skill acquisition.

One of the primary goals of the present study is to consider whether brief bouts of blocked or random practice of the putting action results in superior acquisition and learning as indexed by outcome scores (i.e., putting accuracy) typically assessed in CI studies. A second goal is to consider whether long-term improvement in the golf putt, resulting from either blocked or random practice, is associated with concomitant changes in specific kinematic parameters. In particular we focused on aspects of putting that have previously been identified to change with practice (Delay et al., 1997; Paradisis &

Rees, 2002) such as the amplitude of the BS and DS of the action, movement time of both the BS and DS, velocity at impact, and the putter position at impact. Moreover, where appropriate, this study extended previous work by considering putting in three- (i.e., horizontal, vertical, sagittal) rather than two-dimensions (i.e., horizontal, vertical) to provide a more complete description of this action and the changes that occurred with practice (Delay et al., 1997; Paradisis & Rees, 2002).

With respect to the outcome scores, the initial expectation was that performance would improve, at least during tests of retention and transfer, from brief bouts of random as opposed to blocked practice. Furthermore, while there is a dearth of evidence on the role of CI influencing movement form, there are a few examples in which greater CI led to changes in movement kinematics for single limb and multi-limb coordination tasks (Tsutsui, Lee, & Hodges, 1998). Thus, we anticipated that the kinematic parameters that were highly correlated with successful putting would most likely show greater improvement in random as opposed to blocked practice.

One final issue of interest pertains to whether or not the learners are aware of any movement kinematic changes as they progress through practice. While it seems reasonable to assume a performer is acutely aware of changes in outcome during practice bouts, it is less apparent whether they are privy to the underlying kinematics associated with their performance. Knowledge of the learners' cognitions under different learning conditions may have potential implications for educators and coaches alike in how they might interact with students/athletes during the acquisition of motor or sport-related skills.

A large body of literature exists that examining a learners' thought processes and how the effects of instruction influence what participants think, believe, feel, say, or do that affects achievement (Doyle, 1977,1980; Winne & Marx, 1980; Wittrock, 1986). Wittrock (1986) notes that as a result of the research conducted on learners' thought processes, two related links between teaching and student achievement have been identified. The first links instruction and student cognition while the second link is between participant cognition and learning or achievement. It is the latter link that will be explored in this study using process tracing techniques. Process tracing is a verbal report method that attempts to obtain data on the cognitive processes used by participants as they render judgments and make decisions or solve problems. An additional purpose of the study is to assess the cognitions of the participants during various stages of practice in the performance of the putting skill.

Since learners thoughts cannot 'be read' while conducting tasks in a typical practice setting, they must be captured and warehoused until later when events recorded earlier can be reviewed and discussed. Stimulated recall, one of the process tracing methods and a long recognized method in educational research, enables an individual to revisit an event if provided sufficient prompts or cues. Typical stimulated recall sessions involve videotaping a teaching/learning situation, then replaying it shortly after the event (thus serving as the stimulus) to elicit learners' thought processes. Researchers in physical education settings have used this procedure to examine research topics including teacher planning (Housner & Griffey, 1985), critical thinking (McBride & Bonnette, 1995), and the acquisition of teacher knowledge (Schempp, 1995).

In sum, the purposes of this study are to: (1) examine whether the extent of CI experienced during practice affects acquisition and learning of the golf putting action, (2) consider whether the improvement in the golf putt resulting from low and high CI practice conditions is associated with concomitant changes in specific kinematic parameters, and (3) assess the cognitions of the participants during various stages of practice in the performance of the putting skill.

Methods

Participants

Twenty four undergraduate students (14 male; 10 female) aged 18-22 from Kinesiology 406 Motor Learning and Skill Performance served as participants in the study. Upon completion of the study, all received one credit toward the experiment requirement in their Kinesiology classes. All students were novice putters and signed an informed consent form prior to their participation.

Equipment

Three 5' x 3' x 1' platforms were constructed and covered by a carpeted surface to simulate the texture of a putting green. The surface was made as level as possible to eliminate any curvature of the ball due to the surface. A marker indicated where to place the ball at the starting position. A putter and 36 regulation golf balls consisting of 12 yellow, 12 white, and 12 orange balls were used. Targets (circles of 4 ¼ inches diameter, the same as a real hole) were located at distances of 1.22 m (4 ft), 2.44 m (8 ft), and 3.66 m (12 ft) from the starting position of the ball. Each target was colored yellow (1.22 m), white (2.44 m), or orange (3.66 m) to match the colored balls. For example, a

participant putted the yellow ball to the yellow target (1.22 m), the orange ball to the orange target (3.66 m), and so on.

An OPTOTRAK™ 3020 camera system (Northern Digital, Waterloo Canada) recorded the 3D movement of infrared light-emitting diodes (IRED) attached to the putter head. The OPTOTRAK™ 3020 camera system is a 3D motion-detecting system consisting of three lens assemblies. Each lens has a $34^\circ \times 34^\circ$ field of view and three assembly lenses are precalibrated to a resolution of 0.1 mm in the x and y directions and 0.15 mm in the z direction at a distance of 2.5 m. The IRED signals were sampled at 100 Hz and stored on disk during the experiment for later offline analyses. The camera was mounted on the wall in front of the participant and rotated about 30° to the left at a distance of 2.5 m. A Toshiba VHS camcorder for videotaping was located next to the camera in order to record putting performances for later stimulated recall interviews.

Figure 1 displays a schematic diagram showing the experimental setting and the direction of each axis used for assessing kinematic parameters. Since the OPTOTRAK™ 3020 collects data three dimensionally, it is important to know which axis represents what direction. The x -axis represents movement along the target line, the y -axis represents the vertical motion, and the z -axis represents the horizontal motion perpendicular to the target line (x -axis).

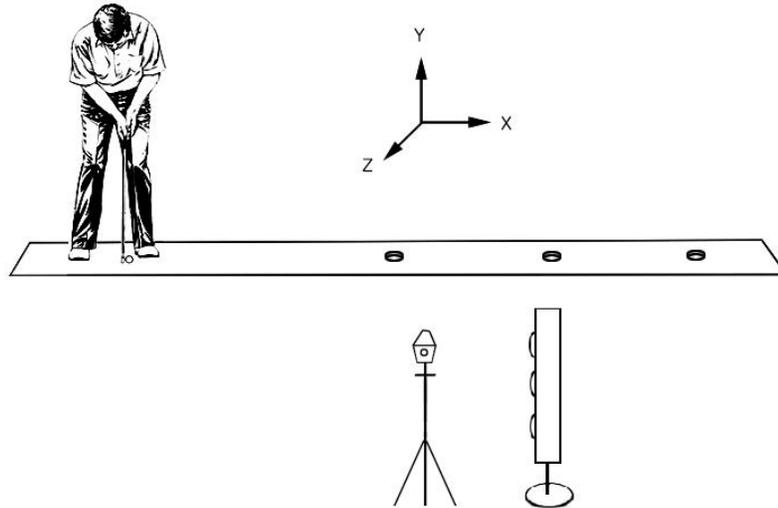


Figure 1. A schematic diagram showing the experimental setting and the direction of each axis used for assessing kinematic parameters.

Task and Procedures

Pre-test

Once informed consents had been signed, all participants performed a pre-test of 30 putts in a blocked order, ten putts to each target. Participants tried to putt as close as possible to the three targets. They were free to initiate their movement whenever they wished. The sampling time was initiated when the participant was ready to putt. Once initiated, the participants had four seconds to perform each putt.

Practice (Acquisition)

Each individual was then randomly assigned to one of two treatment groups (12 participants to each group; blocked or random practice), and given instructions specific to that group. The blocked group was instructed to finish all 36 putts to the 4 ft target before changing to the next target. Random group members were instructed not to putt

to the same target twice in a row. Both groups putted a total of 108 trials (36 to each target) during the Day One practice session. Before performing the first trial, the investigator demonstrated the putting action twice without striking the golf ball. No other instruction occurred.

Post- test (Retention and Transfer Test)

On Day Two (approximately 24 hours after completion of practice), retention and transfer tests were administered. The retention test was identical to the pretest procedure in that all participants performed 30 putts in a blocked order. The transfer test required them to putt to a new target at a distance of 10 ft. All participants performed 10 putts to the new target.

Stimulated Recall Interviews

To further identify any possible differences between the two groups, two participants of each group were selected for videotaping and stimulated-recall interviews on Day One and Day Two. On Day One the investigator stopped the videotape after the 12th, 24th, and 36th putts and asked the participants: (1) Describe what is going on here (2) Is there anything specific you are focusing on? (3) Do you think you are improving? Why? Why not? (4) What are you doing differently here than at the beginning of the trials? (5) How successful do you think you are at this point of practice? Why? Why not? Each interview lasted 30 to 40 minutes.

The identical procedure was followed for the final trial of 36 putts. This protocol was repeated on Day Two except that the videotape was stopped after the 10th, 20th, 30th, and 40th putts respectively. The interviews were audiotaped, transcribed, and

subjected to content analyses. Member checks also occurred to ensure accuracy of the interview data and then the interview data were triangulated with the kinematic data. Finally pseudonyms were used when identifying the four participants.

Dependent Variables and Data Analyses

Performance for each trial and individual was assessed by recording a global error that calculates as the hypotenuse of a right-triangle formed by the intersection of the x -axis (extended horizontally from the center of the target) and the y -axis (extended vertically from the center of the location of the performance result). To assess the kinematics of each putt, the action was assumed to involve two phases: (1) a backswing (BS) phase and (2) a downswing (DS) phase. The BS phase was defined as the backward motion (x -dimension) of the club away from the ball up to the point at which the club reversed direction toward the ball (Figure 2 a). The DS phase was defined as the forward motion (x -dimension) starting from the end of the BS phase to the point at which the club stopped moving in the forward direction (Figure 2 b). This description afforded the opportunity to evaluate each of the following kinematic markers as dependent variables: BS and DS movement amplitude, BS and DS movement time, impact velocity, and putter position at impact. Wherever appropriate, analyses of the kinematic variables were performed in each of x -, y -, and z -dimensions.

For the pretest and retention phases, all dependent variables were subjected to 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVAs with repeated measures on the last factor. For the transfer phase, all dependent variables were subject to a one-way (2: Practice) ANOVA. In the case of the acquisition phase, each dependent

variable was subjected to separate 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVAs with repeated measure on the last two factors. Any significant effects were further analyzed using the Student-Newman-Keuls (S-N-K) follow-up procedure. All significant effects were identified at the $p < .05$ level.

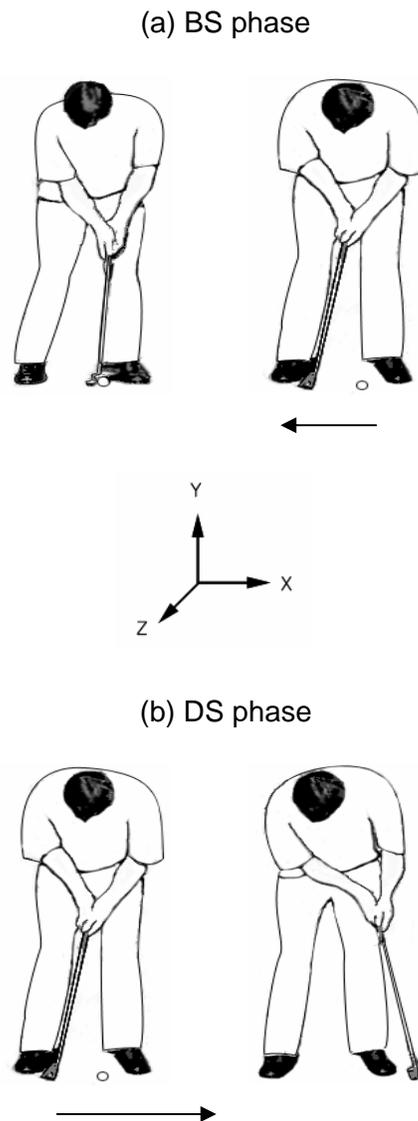


Figure 2. A schematic diagram showing the BS and DS phases of putting.

For the stimulated-recall data, interviews were recorded, transcribed and subjected to content analysis to search for any similarities and differences of cognitive processing between the two groups. Once transcribed the interviews were coded and unitized by three members of the research team. Each coded card identified the participant, group, day (one or two), number of trials, page number from the interview, and card number. Analyses of the interviews produced categories derived inductively and are described in the results section. Disagreements regarding coding were discussed until 100% agreement resulted, so that all final coding was consensual.

Results: Part One

For the purpose of analyses, mean global error as well as the mean and standard deviations for each kinematic variable were calculated for each set of 18 trials for each individual in acquisition and each set of 10 trials for each individual in the pretest, retention, and transfer phases.

Pre-test

Figure 3 displays mean global error during the pre-test, acquisition, retention, and transfer phases as a function of the blocked and random practice conditions. The 2 (Practice: blocked, random) x 6 (Block: 1-6) ANOVA with repeated measures on the last factor on the global error data was not significant. In general, there was also a lack of significant differences for each kinematic parameter as a function of both practice condition and distance. Prior to the acquisition phase, all individuals performed the putting action with similar accuracy and kinematic profiles.

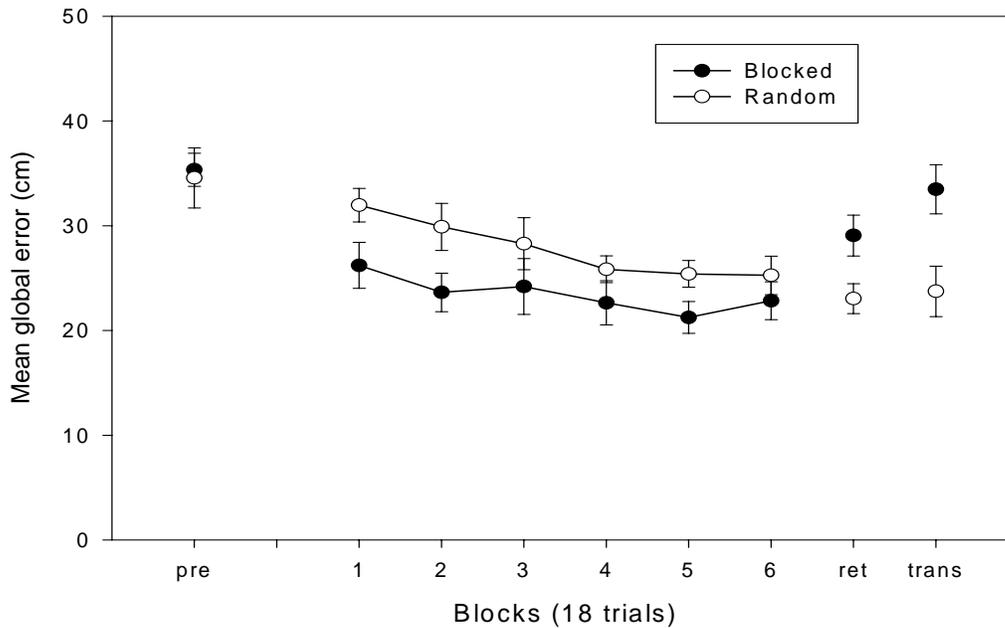


Figure 3. Mean global error during the pre-test, acquisition, retention, and transfer phases as a function of the blocked and random practice conditions.

Acquisition Phase

Mean Global Error

The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last factor for mean global error revealed significant main effects of practice, $F(1, 22) = 6.13, p < .05$, distance, $F(2, 44) = 36.56, p < .01$, and block, $F(5, 110) = 3.32, p < .01$. Simple main effects analyses indicated that mean global error for Block 1 ($M = 29$ cm, $SEM = 1$ cm) was significantly greater than the global error observed for Blocks 4 ($M = 24$ cm, $SEM = 1$ cm), 5 ($M = 23$ cm, $SEM = 1$ cm), and 6 ($M = 24$ cm, $SEM = 1$ cm). In addition, mean global error was significantly lower for the blocked practice participants ($M = 23$ cm, $SEM = 2$ cm)

compared to their random practice counterparts ($M = 28$ cm, $SEM = 2$ cm). Post hoc analyses indicated that mean global error for the 4 ft distance ($M = 16$ cm, $SEM = 1$ cm) was significantly lower than the 8 ft ($M = 30$ cm, $SEM = 2$ cm) and the 12 ft ($M = 30$ cm, $SEM = 2$ cm) distances. The 8 ft distance was not significantly different from the 12 ft distance. Blocked practice participants showed superior performance compared to their random practice counterparts during acquisition. Moreover, performance generally improved across practice blocks.

Swing Characteristics: Backswing (BS)

Mean amplitude: x-dimension. For mean amplitude on the BS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last two factors revealed a significant main effect of distance, $F(2,44) = 72.89$, $p < .01$. Subsequent post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = 12$ cm, $SEM = 1$ cm) was significantly different from the 8 ft ($M = 16$ cm, $SEM = 1$ cm), and the 12 ft ($M = 20$ cm, $SEM = 1$ cm) distances. The 8 ft distance was also significantly different from 12 ft distance. No other main effects or interactions were significant.

Mean amplitude: y-dimension. With respect to mean amplitude on the BS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last two factors revealed a significant main effect of distance, $F(2,44) = 50.59$, $p < .01$. Post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = .88$ cm, $SEM = .12$ cm) was significantly different from the 8 ft ($M = 1.22$ cm, $SEM = .10$ cm), and the 12 ft ($M = 1.71$ cm, $SEM = .15$ cm) distances. The 8

ft distance was also significantly different from the 12 ft distance. No other main effects or interactions were significant.

Mean amplitude: z-dimension. For mean amplitude on the BS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last two factors revealed a significant main effect of distance, $F(2,44) = 28.07, p < .01$. Post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = -.40$ cm, $SEM = .12$ cm) was significantly different from the 8 ft ($M = -.52$ cm, $SEM = .10$ cm), and the 12 ft ($M = -.90$ cm, $SEM = .15$ cm) distances. The 8 ft distance was also significantly different from the 12 ft distance. No other main effects or interactions were significant. These data indicated that the amplitude of the BS movement increased with the increasing distance to the targets in all three dimensions.

Amplitude variability: x-dimension. Figure 4 portrays that amplitude variability in the x-dimension for the blocked and random practice condition as a function of putting distance and practice block. The 2 (Practice: Random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors revealed main effects of practice, $F(1,22) = 7.45, p < .01$, distance, $F(2, 44) = 13.53, p < .01$, and block, $F(5, 110) = 5.53, p < .01$. In addition, interactions of Practice x Distance, $F(2, 44) = 5.92, p < .01$, Practice x Block, $F(5,110) = 5.84, p < .01$, and Distance x Block, $F(10, 220) = 2.96, p < .01$, were significant. Interpretation of the significant main and interactive effects must be made in light of the significant Practice x Distance x Block interaction, $F(10, 220) = 3.53, p < .01$. Post hoc analyses indicated that the variability in BS amplitude was larger in the random practice participants at the 4 ft (M

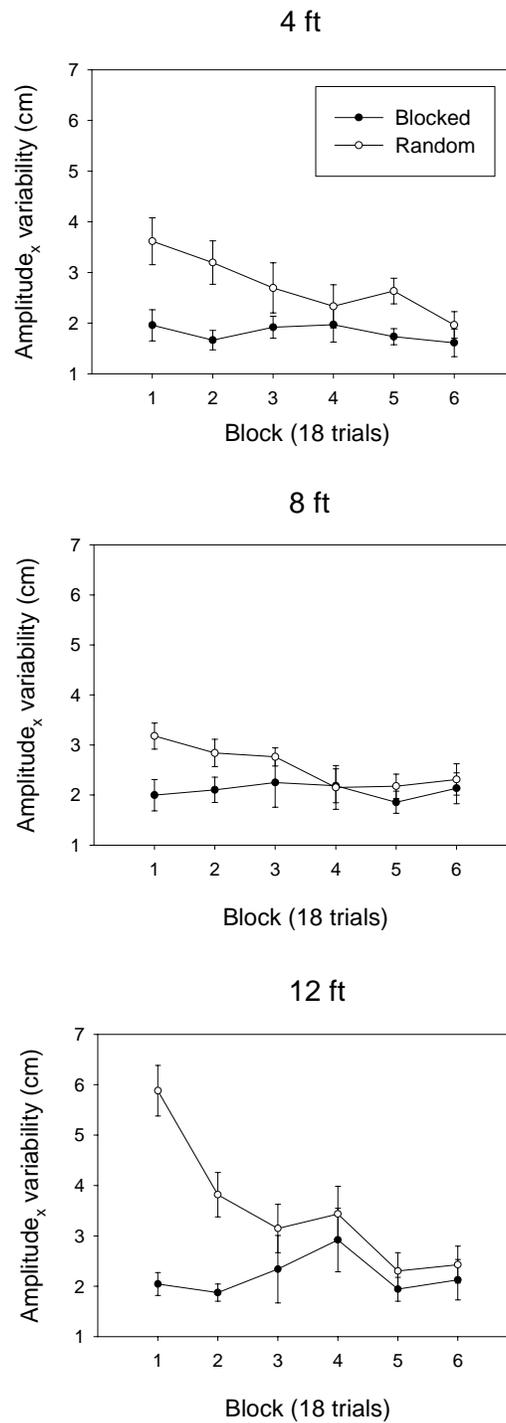


Figure 4. Amplitude variability in the x -dimension for the blocked and random practice conditions as a function of putting distance and practice block.

= 3 cm, $SEM = .39$ cm) and the 12 ft ($M = 4$ cm, $SEM = .45$ cm) compared to the blocked practice participants at the 4 ft ($M = 2$ cm, $SEM = .25$ cm) and the 12 ft ($M = 2$ cm, $SEM = .39$ cm) distances. There was no significant difference at the 8 ft distance between the two groups. Post hoc analyses also indicated that BS variability in Blocks 1 ($M = 4$ cm, $SEM = .41$ cm), 2 ($M = 3$ cm, $SEM = .38$ cm) and 5 ($M = 2.40$ cm, $SEM = .29$ cm) of the random practice participants was significantly larger than those of the blocked practice participants at Blocks 1 ($M = 2$ cm, $SEM = .28$ cm), 2 ($M = 2$ cm, $SEM = .20$ cm), and 5 ($M = 2$ cm, $SEM = .21$ cm). These data are congruent with previous reports under the guise of impulse variability theory (Schmidt, Zelaznic, Hawkins, Frank, & Quinn, Jr., 1979) that predicts greater spatial error occurs with greater force production.

Amplitude variability: y-dimension. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for amplitude variability revealed a main effect of distance, $F(2, 44) = 10.06$, $p < .01$. Post hoc analyses revealed that the amplitude variability of the BS in the y-dimension for the 12 ft distance ($M = .48$ cm, $SEM = .06$ cm) was significantly larger than the 4 ft ($M = .33$ cm, $SEM = .05$ cm) and 8 ft ($M = .37$ cm, $SEM = .04$ cm) distances.

Amplitude variability: z-dimension. No significant effects were found.

Mean movement time. Figure 5 displays mean movement time and movement time variability for the BS as a function of putting distance. With respect to mean movement time (MT) of the BS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last two factors revealed a significant main effect of distance, $F(2, 44) = 7.84$, $p < .01$. Post hoc analyses

indicated that mean MT for the BS for the 4 ft distance ($M = 1.10$ sec, $SEM = .06$ sec) was significantly different from the 8 ft ($M = 1.17$ sec, $SME = .07$ sec) and 12 ft ($M = 1.21$ sec, $SEM = .08$ sec) distances. Mean MT for the BS for the 8 ft target was significantly less than that observed for the 12 ft distance. No other main effects or interactions were significant.

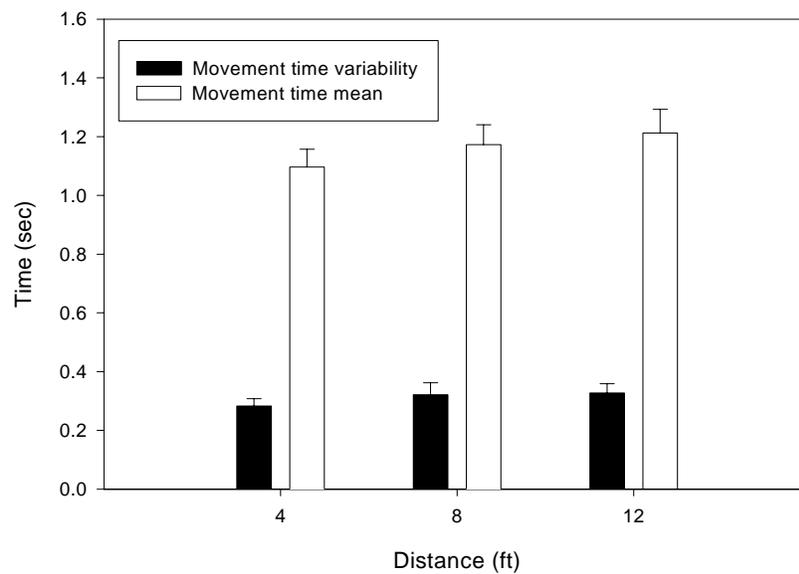


Figure 5. Mean movement time and movement time variability for the BS as a function of putting distance.

Movement time variability. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for the variability in MT revealed a significant main effect of distance, $F(2, 44) = 6.76$, $p < .01$. Post hoc analyses indicated that BS movement time variability at the 4 ft distance ($M = .28$ sec, $SEM = .03$ sec) was significantly less than at the 8 ft ($M = .32$ sec, $SEM = .04$ sec) and the 12 ft ($M = .33$ sec, $SEM = .03$ sec) distances. There was no

significance between 8 ft and 12 ft distances. No other main effects or interactions were significant.

Swing Characteristics: Downswing (DS)

Mean amplitude: x-dimension. For mean amplitude on the DS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last two factors revealed a significant main effect of distance, $F(2,44) = 28.61, p < .01$. Post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = 30$ cm, $SEM = 2$ cm) was significantly different from the 8 ft ($M = 42$ cm, $SEM = 2$ cm), and the 12 ft ($M = 53$ cm, $SEM = 3$ cm) distances. The 8 ft distance was also significantly different from 12 ft distance. No other main effects or interactions were significant.

Mean amplitude: y-dimension. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last two factors revealed significant main effects of distance, $F(2,44) = 37.24, p < .01$. Post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = 3$ cm, $SEM = .27$ cm) was significantly different from the 8 ft ($M = 4$ cm, $SEM = .42$ cm), and the 12 ft ($M = 6$ cm, $SEM = .76$ cm) distances. The 8 ft distance was also significantly different from 12 ft distance. No other main effects or interactions were significant.

Mean amplitude: z-dimension. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last two factors revealed a significant main effect of distance, $F(2,44) = 8.77, p < .01$. Post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = .28$ cm, $SEM = .23$ cm) was

significantly different from the 8 ft ($M = -.24$ cm, $SEM = .42$ cm), and the 12 ft ($M = -.90$ cm, $SEM = .55$ cm) distances. The 8 ft distance was also significantly different from 12 ft distance. No other main effects or interactions were significant. Thus, with respect to mean amplitude, the data from the DS phase was very similar to the BS phase. That is, with increasing distance to the target, mean amplitude of the DS increased.

Amplitude variability: x-dimension. Figure 6 displays DS amplitude variability in the x -dimension for the blocked and random practice conditions for each putting distance as a function of acquisition. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for amplitude variability revealed a significant main effect of practice, $F(1, 22) = 16.66$, $p < .01$. In addition, interactions of Practice x Block, $F(5, 110) = 4.66$, $p < .01$ and Practice x Distance $F(2, 44) = 6.93$, $p < .01$ were significant. Interpretation of the significant main and interactive effects must be made in light of the significant interaction of Practice x Distance x Block, $F(10, 220) = 3.56$, $p < .01$. Post hoc analyses indicated that variability at 12 ft distance ($M = 7$ cm, $SEM = 1$ cm) for the random practice participants was significantly larger than that ($M = 4$ cm, $SEM = .69$ cm) for the blocked practice participants. Post hoc analyses also revealed that Blocks 1 ($M = 21$ cm, $SEM = 7$ cm) and 2 ($M = 20$ cm, $SEM = 7$ cm) of the random practice participants were significantly larger than Blocks 1 ($M = 13$ cm, $SEM = 4$ cm) and 2 ($M = 12$ cm, $SEM = 4$ cm) of the blocked practice participants.

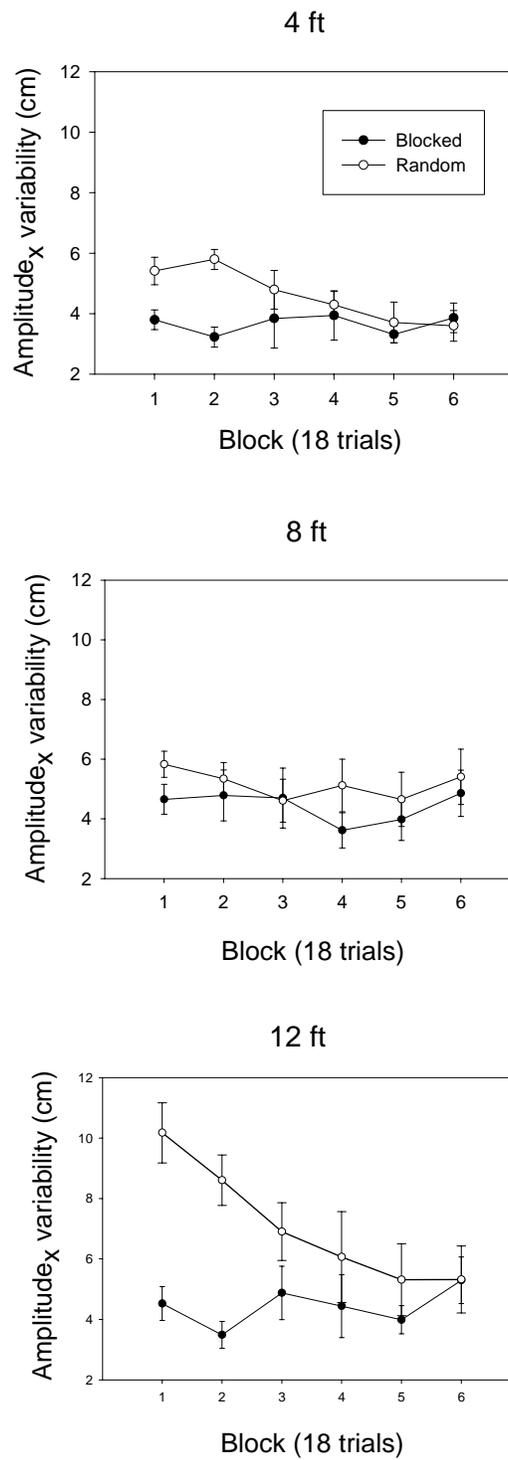


Figure 6. DS amplitude variability in the x -dimension for the blocked and random practice conditions for each putting distance as a function of acquisition.

Amplitude variability: y-dimension. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for amplitude variability revealed a main effect of distance, $F(2, 44) = 22.13$, $p < .01$, and block, $F(5, 110) = 3.16$, $p < .01$. Post hoc analyses indicated that amplitude variability for the 4 ft distance ($M = .85$ cm, $SEM = .13$ cm) was significantly different from the 8 ft ($M = 1.20$ cm, $SEM = .27$ cm), and the 12 ft ($M = 1.59$ cm, $SEM = .27$ cm) distances. The 8 ft distance was also significantly different from the 12 ft distance. Post hoc analyses indicated that Block 1 ($M = .96$ cm, $SEM = .09$ cm) was significantly lower than Block 3 ($M = 1.49$ cm, $SEM = .36$ cm). No other main effects or interactions were significant.

Amplitude variability: z-dimension. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for amplitude variability was not significant.

Mean movement time. The 2 (Practice: Random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for mean movement time was not significant.

Movement time variability. Figure 7 shows mean movement time and movement time variability for the DS as a function of putting distance. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for movement time variability revealed a significant main effect of distance, $F(2, 44) = 10.67$, $p < .01$. Post hoc analyses showed that movement time variability of the DS at the 4 ft distance ($M = .50$ sec, $SEM = .09$ sec)

was significantly larger than the 12 ft distance ($M = .34$ cm, $SEM = .07$ cm). No other main effects or interactions were significant.

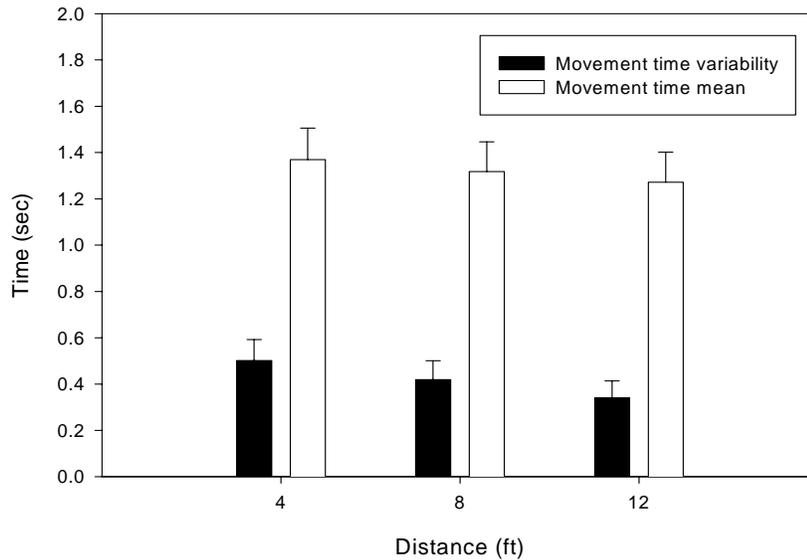


Figure 7. Mean movement time and movement time variability for the DS as a function of putting distance.

Impact Characteristics: Impact Velocity

The velocity of the DS was calculated using a 3-point difference algorithm. The point associated with the initial putter position was taken as the impact point. Impact velocity was the velocity value of the DS in the x -dimension when the club passed back through the initial point.

Mean impact velocity. With respect to mean impact velocity, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Block: 1-6) ANOVA with repeated measures on the last two factors revealed a significant main effect of distance, $F(2, 44) = 581.52, p < .01$. Post hoc analyses indicated that mean impact velocity of the 4 ft distance

($M = 58$ cm/sec, $SEM = .79$ cm/sec) was significantly different from the 8 ft ($M = 78$ cm/sec, $SEM = .89$ cm/sec), and the 12 ft ($M = 95$ cm/sec, $SEM = 1.39$ cm/sec) distances. The 8 ft distance was also significantly different from the 12 ft distance. No other main effects or interactions were significant. The data indicate that mean impact velocity was significantly increased with increasing distance of the target.

Impact velocity variability. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures of the last two factors for impact velocity variability revealed significant main effects of practice, $F(1, 22) = 4.91, p < .05$, distance, $F(2, 44) = 40.92, p < .01$, and block, $F(5, 110) = 2.99, p < .05$. In addition, the Practice x Distance, $F(2, 44) = 8.74, p < .01$, and Practice x Block interactions, $F(5, 110) = 3.09, p < .05$ were significant. No other main effects or interactions were significant.

With respect to the Practice x Distance interaction, post hoc analyses indicated the 4 ft distance ($M = 6$ cm/sec, $SEM = .98$ cm/sec) of the random group participants had significantly larger variability than the blocked practice participants ($M = 5$ cm/sec, $SEM = .55$ cm/sec). Post hoc analyses also revealed that the 12 ft distance ($M = 9$ cm/sec, $SEM = .79$ cm/sec) of the random group participants had significantly larger variability than that of the blocked practice participants ($M = 8$ cm/sec, $SEM = .76$ cm/sec). These data are depicted in Figure 8. Figure 9 shows that impact velocity variability for blocked and random practice for acquisition. Post hoc analyses revealed that the random practice participants had significantly larger variability on Blocks 1 ($M = 9$ cm/sec, $SEM = 1.20$ cm/sec) and 2 ($M = 9$ cm/sec, $SEM = .96$ cm/sec) compared to the blocked practice

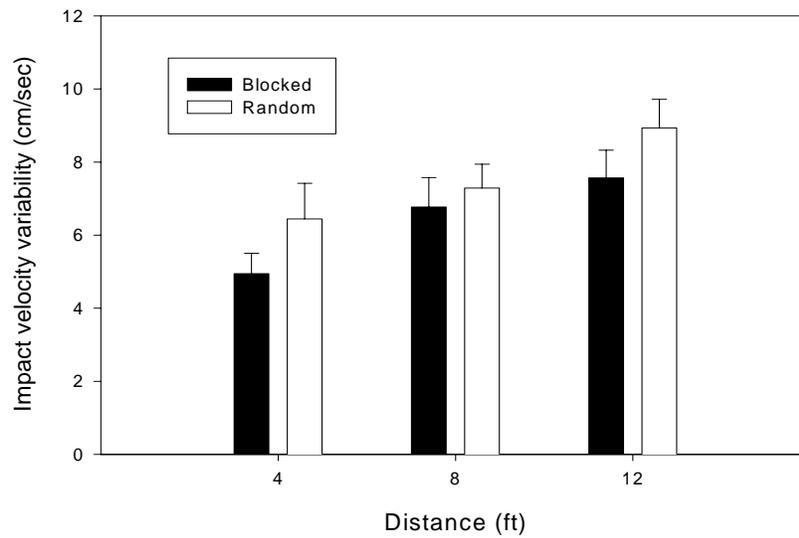


Figure 8. Variability of impact velocity for blocked and random practice of each distance.

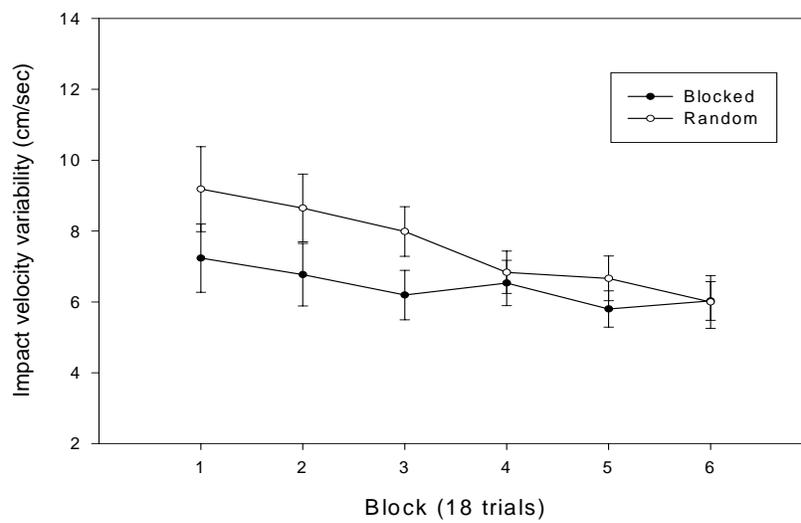


Figure 9. Impact velocity variability for blocked and random practice for acquisition.

participants on Blocks 1 ($M = 7$ cm/sec, $SEM = .96$ cm/sec) and 2 ($M = 7$ cm/sec, $SEM = .88$ cm/sec). Impact velocity variability did not differ as a function of practice condition for Blocks 3, 4, 5, and 6. These data indicate that individuals in the random practice condition exhibited greater variability in impact velocity early in practice. In addition, the larger variability in impact velocity for the random practice participants was exaggerated as distances increased.

Impact Characteristics: Putter Position

An important characteristic of putting is to strike the ball with the center of the putter head (i.e., sweet spot). To assess the performer's ability to accomplish this, we evaluated club head position in the z -dimension. When the putter returned to the initial start position depicted as "0" position in the x -dimension. A negative z -value indicates contact close to the heel, while a positive z -value indicates contact closer to the toe of the club.

Z-dimension: mean. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for mean putter position was not significant.

Z-dimension: variability. The 2 (Practice: random, blocked) x 3 (Distance: 4 ft, 8 ft, 12 ft) x 6 (Blocks: 1-6) ANOVA with repeated measures on the last two factors for putter position variability revealed significant main effects of practice, $F(1, 22) = 4.89$, $p < .05$, and block, $F(5, 110) = 5.79$, $p < .01$. Figure 10 displays variability of putter position for blocked and random practice for each block of acquisition. Post hoc analyses showed that Block 1 ($M = .51$ cm, $SEM = .04$ cm) was significantly larger than

Blocks 3 ($M = .43$ cm, $SEM = .06$ cm), 4 ($M = .40$ cm, $SEM = .05$ cm), 5 ($M = .38$ cm, $SEM = .05$ cm), and 6 ($M = .39$ cm, $SEM = .05$ cm), and the random practice participants ($M = .46$ cm, $SEM = .05$ cm) had significantly larger variability compared to blocked practice participants ($M = .39$ cm, $SEM = .05$ cm). The data show that variability in putter position at impact decreased as practice progressed with the blocked practice participants having smaller variability in putter position at impact.

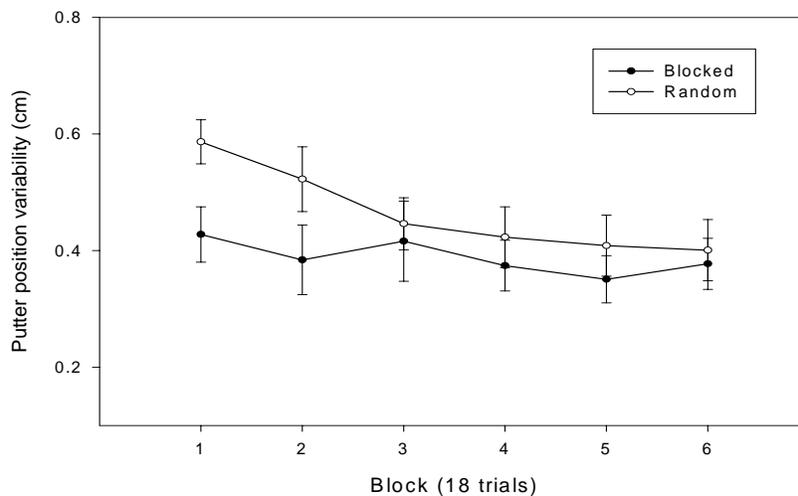


Figure 10. Variability of putter position for blocked and random practice for each block of acquisition.

Retention Phase

Mean Global Error

Figure 2 presents mean global error during the pre-test, acquisition, retention, and transfer phases as a function of the blocked and random practice conditions. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for mean global error revealed significant main effects on

practice, $F(1,22) = 6.21, p < .01$, and distance, $F(2, 44) = 19.94, p < .01$. Simple main effect analyses indicated that the mean global error for the random practice participants ($M = 23$ cm, $SEM = 1$ cm) was significantly lower than the blocked practice participants ($M = 29$ cm, $SEM = 2$ cm). Post hoc analyses showed that mean global error for the 4 ft distance ($M = 16$ cm, $SEM = 2$ cm) was significantly lower than the 8 ft ($M = 31$ cm, $SEM = 2$ cm), and the 12 ft ($M = 32$ cm, $SEM = 2$ cm) distances. The 8 ft distance was not significantly different from the 12 ft distance. The random practice participants putting performance was significantly more accurate than the blocked practice participants during the retention phase. That is, there was less mean global error indicating that the random group putted closer to the respective targets.

Swing Characteristics: Backswing (BS)

Mean amplitude: x-dimension. For mean amplitude on the BS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor revealed a significant main effect of distance, $F(2, 44) = 77.94, p < .01$. Subsequent post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = 11$ cm, $SEM = .50$ cm) was significantly different from the 8 ft ($M = 16$ cm, $SEM = .70$ cm), and the 12 ft ($M = 19$ cm, $SEM = .80$ cm) distances. The 8 ft distance was also significantly different from the 12 ft distance. No other main effects or interactions were significant.

Mean amplitude: y-dimension. With respect to mean amplitude on the BS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor revealed a significant main effect of distance, $F(2, 44) =$

40.88, $p < .01$. Post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = .87$ cm, $SEM = .08$ cm) was significantly different from the 8 ft ($M = 1.29$ cm, $SEM = .12$ cm), and the 12 ft ($M = 1.64$ cm, $SEM = .13$ cm) distances. The 8 ft distance was also significantly different from the 12 ft distance. No other main effects or interactions were significant.

Mean amplitude: z-dimension. For mean amplitude on the BS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor showed a significant main effect for distance, $F(2, 44) = 1.17, p < .01$. Post hoc analyses indicated that the mean amplitude at the 4 ft target distance ($M = .19$ cm, $SEM = .10$ cm) was significantly different from the 8 ft ($M = .54$ cm, $SEM = .15$ cm) and the 12 ft ($M = .68$ cm, $SEM = .14$ cm) distances. No other main effects or interactions were significant. Like the practice phase, participants continued to adopt the strategy of increasing amplitude of the BS movement as target distance increased.

Amplitude variability: x-dimension. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for amplitude variability was not significant.

Amplitude variability: y-dimension. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for amplitude variability revealed a main effect of distance, $F(2, 44) = 5.14, p < .01$. No other main effects or interactions were significant. Post hoc analyses indicated that BS amplitude variability at the 4 ft distance ($M = .28$ cm, $SEM = .03$ cm) was significantly

smaller than the 8 ft distance ($M = .41$ cm, $SEM = .05$ cm). The 12 ft distance ($M = .35$ cm, $SEM = .02$ cm) was not significantly different from either 4 ft or 8 ft distances.

Amplitude variability: z-dimension. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for amplitude variability was not significant.

Mean movement time. Figure 11 shows mean movement time and movement time variability for the BS as a function of putting distance for retention. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for mean movement time revealed a main effect of distance, $F(2, 44) = 4.68$, $p < .05$. Post hoc analyses showed that mean movement time at the 4 ft distance ($M = 1.00$ sec, $SEM = .04$ sec) was significantly shorter than the 8 ft ($M = 1.09$ sec, $SEM = .04$ sec) and the 12 ft ($M = 1.13$ sec, $SEM = .05$ sec) distances. There was no significant difference in mean movement time between the 8 ft and the 12 ft distance. No other main effects or interactions were significant.

Movement time variability. Figure 12 illustrates movement time variability for the BS for blocked and random practice of each distance during the retention phase. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for BS movement time variability produced a significant Practice x Distance interaction, $F(2, 44) = 3.46$, $p < .05$. Post hoc analyses indicated that the blocked practice participants for movement time variability at the 8 ft target distance ($M = .34$ sec, $SEM = .04$ sec) was significantly greater than the random practice participants ($M = .22$ sec, $SEM = .02$ sec).

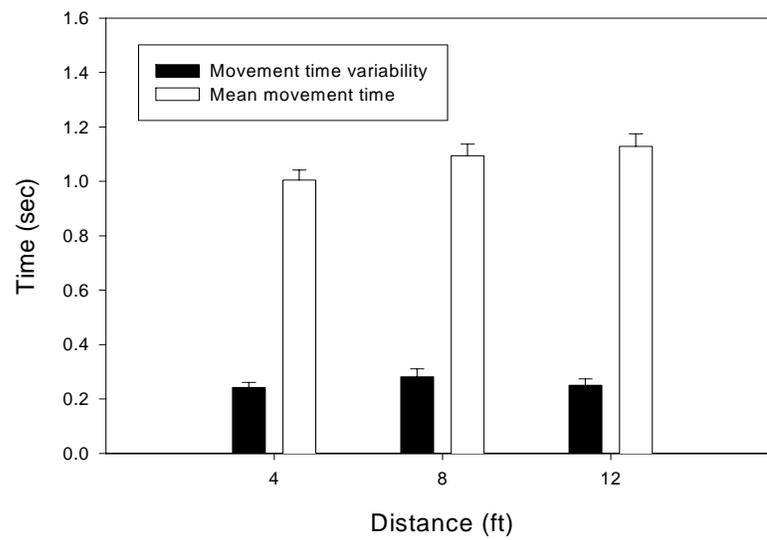


Figure 11. Mean movement time and movement time variability for the BS as a function of putting distance for retention.

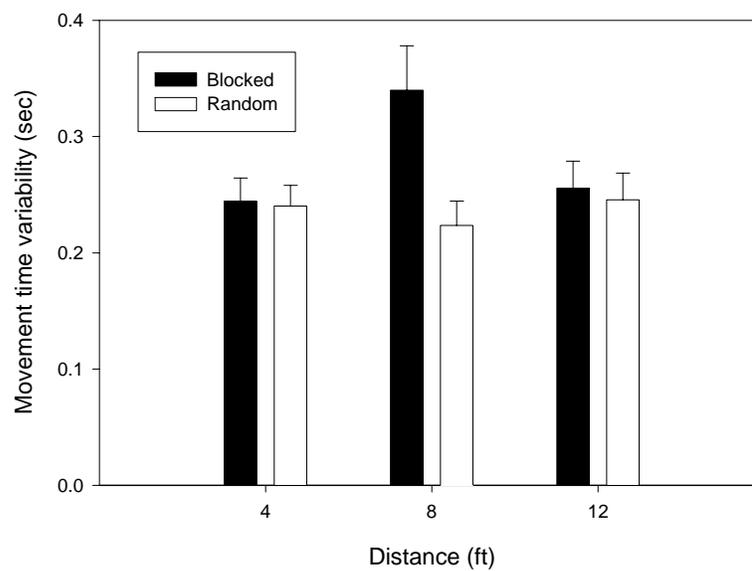


Figure 12. Movement time variability for the BS for blocked and random practice of each distance during the retention phase.

Swing Characteristics: Downswing (DS)

Mean amplitude: x-dimension. For mean amplitude on the DS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for mean amplitude revealed a significant main effect of distance, $F(2, 44) = 58.75, p < .01$. Post hoc analyses indicated that mean amplitude for the 4 ft distance ($M = 27$ cm, $SEM = 1$ cm) was significantly different from the 8 ft ($M = 42$ cm, $SEM = 2$ cm), and the 12 ft ($M = 50$ cm, $SEM = 2$ cm) distances. The 8 ft distance was also significantly different from 12 ft distance. No other main effects or interactions were significant. Overall, the mean DS amplitude in the x -dimension increased with increasing distance to the target.

Mean amplitude: y-dimension. For mean amplitude on the DS, the 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor revealed a significant main effect of distance, $F(2, 44) = 11.02, p < .01$. Post hoc analyses showed that mean amplitude at the 4 ft distance ($M = 3$ cm, $SEM = .30$ cm) was significantly different from the 8 ft ($M = 4$ cm, $SEM = .65$ cm) and the 12 ft ($M = 6$ cm, $SEM = .93$ cm) distances. No other main effects or interactions were significant. These results provided an indication that mean DS amplitude in the y -dimension increased with increasing distance to the targets.

Mean amplitude: z-dimension. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for mean amplitude was not significant.

Amplitude variability: x-dimension. Figure 13 shows DS amplitude variability in the *x*-dimension for blocked and random practice as a function of putting distance during the retention phase. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for amplitude variability revealed main effects of practice, $F(1, 22) = 43.87, p < .01$, and distance, $F(2, 44) = 10.86, p < .01$. The Practice x Distance interaction, $F(2, 44) = 9.15, p < .01$ was also significant. Post hoc analyses showed that amplitude variability at the 4 ft ($M = 3$ cm, $SEM = .38$ cm) and 12 ft target distances ($M = 5$ cm, $SEM = .51$ cm) for the random practice participants were significantly smaller than the 4ft ($M = 7$ cm, $SEM = .33$ cm) and the 12 ft ($M = 9$ cm, $SEM = .89$ cm) distances for the blocked practice participants. Post hoc analyses indicated that amplitude variability was significantly smaller for the random practice participants ($M = 4$ cm, $SEM = .49$ cm) compared to their blocked practice counterparts ($M = 7$ cm, $SEM = .61$ cm). Post hoc analyses also showed that amplitude variability at the 12 ft distance ($M = 7$ cm, $SEM = .70$ cm) was significantly larger than at the 4 ft ($M = 5$ cm, $SEM = .36$ cm) and the 8 ft ($M = 4$ cm, $SEM = .58$ cm) distances. No other main effects or interactions were significant.

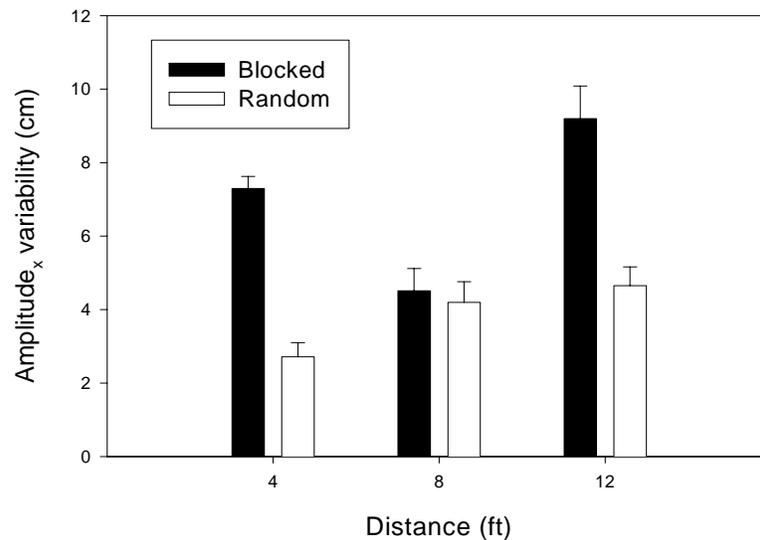


Figure 13. DS amplitude variability in the x -dimension for blocked and random practice as a function of putting distance during the retention phase.

Amplitude variability: y-dimension. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for amplitude variability revealed a main effect of distance, $F(2, 44) = 4.81, p < .05$. Post hoc analyses indicated that amplitude variability at the 4 ft distance ($M = .81$ cm, $SEM = .11$ cm) was significantly smaller than the 8 ft ($M = 1.18$ cm, $SEM = .20$ cm) and the 12 ft ($M = 1.35$ cm, $SEM = .20$ cm) distances. No other main effects or interactions were significant. Again, amplitude variability increased with increasing distance to the target.

Amplitude variability: z-dimension. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for amplitude variability produced a main effect of distance, $F(2, 44) = 7.47, p < .01$. Post hoc analyses indicated that amplitude variability at the 4 ft distance ($M = .88$ cm, SEM

= .07 cm) was significantly smaller than the 8 ft ($M = 1.14$ cm, $SEM = .10$ cm) and the 12 ft ($M = 1.39$ cm, $SEM = .12$ cm) distances. No other main effects or interactions were significant. In sum, amplitude variability increased with increasing distance to the target.

Mean movement time. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for amplitude variability was not significant.

Movement time variability. Figure 14 shows movement time variability of the DS for each distance during the retention phase. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for movement time variability revealed a main effect of distance, $F(2, 44) = 3.83, p < .05$. Post hoc analyses showed that DS movement time variability at the 4 ft distance ($M = .43$ sec, $SEM = .08$ sec) was significantly larger than the 8 ft ($M = .36$ sec, $SEM = .07$ sec) and the 12 ft ($M = .35$ sec, $SEM = .07$ sec) distances. No other main effects or interactions were significant. These results showed that the shorter distances produced greater variability.

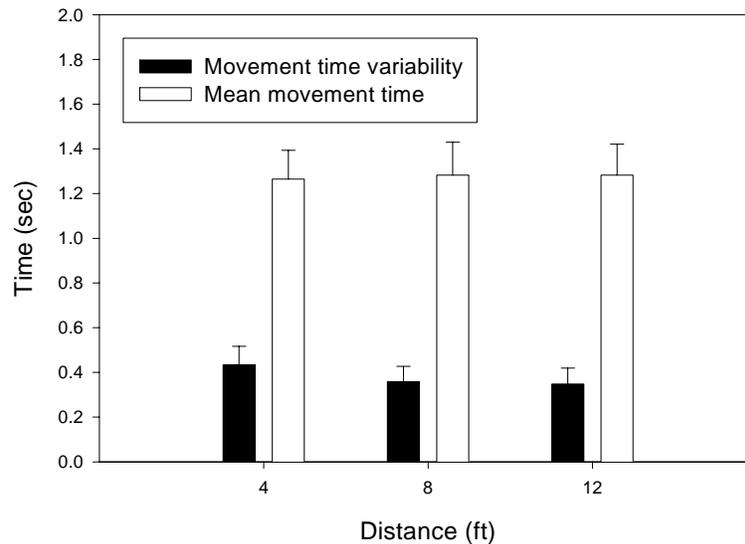


Figure 14. Movement time variability of the DS for each distance during the retention phase.

Impact Characteristics: Impact Velocity

Mean impact velocity. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for mean impact velocity resulted in a main effect of distance, $F(2, 44) = 873.48, p < .01$. Post hoc analyses confirmed that mean impact velocity of the 4 ft distance ($M = 58$ cm/sec, $SEM = .86$ cm/sec) was significantly different from the 8 ft ($M = 79$ cm/sec, $SEM = 1$ cm/sec), and the 12 ft ($M = 96$ cm/sec, $SEM = 1$ cm/sec) distances. The 8 ft distance was also significantly different from the 12 ft distance. No other main effects or interactions were significant. The results indicate that mean impact velocity increased significantly as the target distance increased.

Impact velocity variability. Figure 15 illustrates that variability of impact velocity for blocked and random practice for retention. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for impact velocity variability revealed a main effect of practice, $F(1, 22) = 4.81$, $p < .05$. Post hoc analyses indicated that impact velocity variability for the random practice participants ($M = 6$ cm/sec, $SEM = .60$ cm/sec) was significantly smaller than that of the blocked practice participants ($M = 8$ cm/sec, $SEM = .66$ cm/sec). No other main effects or interactions were significant.

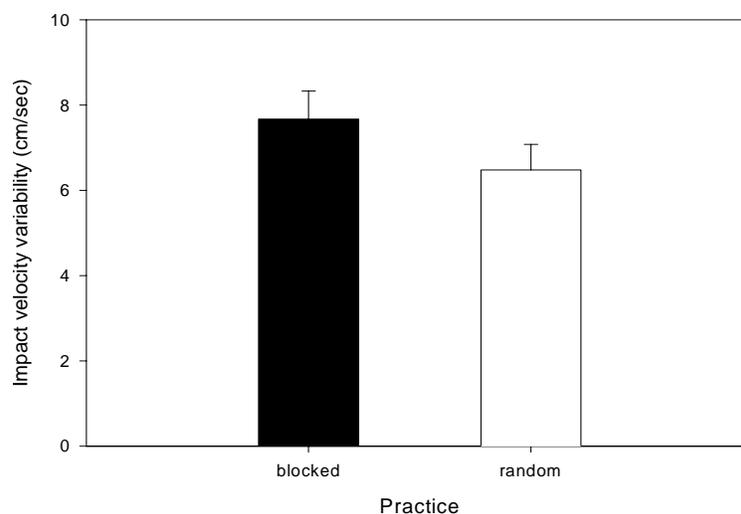


Figure 15. Variability of impact velocity for blocked and random practice for retention.

Impact Characteristics: Putter Position

Z-dimension: mean. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) ANOVA with repeated measures on the last factor for mean putter position was not significant.

Z-dimension: variability. The 2 (Practice: blocked, random) x 3 (Distance: 4 ft, 8 ft, 12 ft) analyses of variance ANOVA with repeated measures on the last factor for putter position variability produced main effects of practice, $F(1, 22) = 30.53, p < .01$, and distance, $F(2, 44) = 3.69, p < .05$. Post hoc analyses revealed that putter position variability at the 4 ft distance ($M = .37$ cm, $SEM = .04$ cm) was significantly smaller than the 12 ft distance ($M = .48$ cm, $SEM = .04$ cm). Figure 16 displays variability of putter position for blocked and random practice during the retention phase. Post hoc analyses indicated that the random practice participants ($M = .33$ cm, $SEM = .03$ cm) had significantly smaller variability than the blocked practice participants ($M = .51$ cm, $SEM = .08$ cm). No other main effects or interactions were significant. In sum, putter position variability increased as target distance increased and the random practice participants had smaller variability.

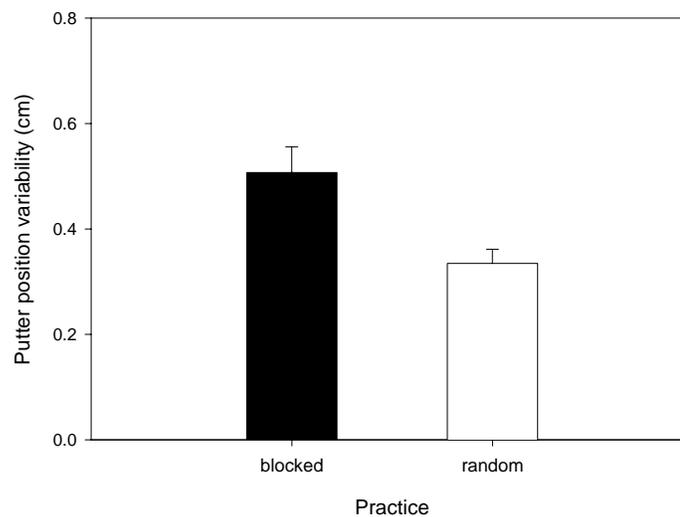


Figure 16. Variability of putter position for blocked and random practice during the retention phase.

Transfer Phase

Mean Global Error

The one-way (Practice: blocked, random) ANOVA for mean global error produced a significant main effect of practice, $F(1, 22) = 8.40, p < .01$. With the mean global error for the random practice participants ($M = 24$ cm, $SME = 2$ cm) significantly lower than the blocked practice participants ($M = 33$ cm, $SME = 2$ cm). Random practice participants were more accurate than blocked practice participants during the transfer phase.

Swing Characteristics: Backswing (BS)

Mean amplitude. The one-way (Practice: blocked, random) ANOVA for mean amplitude was not significant.

Amplitude variability: x-dimension. The one-way (Practice: blocked, random) ANOVA for amplitude variability was not significant.

Amplitude variability: y-dimension. The one-way (Practice: blocked, random) ANOVA for amplitude variability was not significant.

Amplitude variability: z-dimension. The one-way (Practice: blocked, random) ANOVA for amplitude variability indicated a significant main effect of practice, $F(1, 22) = 6.75, p < .05$. Random practice participants ($M = .47$ cm, $SEM = .05$ cm) had significantly smaller variability than blocked practice participants ($M = .68$ cm, $SEM = .07$ cm).

Mean movement time. The one-way (Practice: blocked, random) ANOVA for mean movement time was not significant.

Movement time variability. The one-way (Practice: blocked, random) ANOVA for movement time variability was not significant.

Swing Characteristics: Downswing (DS)

Mean amplitude. The one-way (Practice: blocked, random) ANOVA for mean amplitude was not significant.

Amplitude variability: x-dimension. The one-way (Practice: blocked, random) ANOVA for amplitude variability indicated a significant effect of practice, $F(1, 22) = 4.57, p < .05$. Figure 17 shows amplitude variability of the DS in the x -dimension for blocked and random practice for the transfer phase. Random practice participants ($M = 5$ cm, $SEM = .38$ cm) had significantly smaller variability than blocked practice participants ($M = 9$ cm, $SEM = 2$ cm).

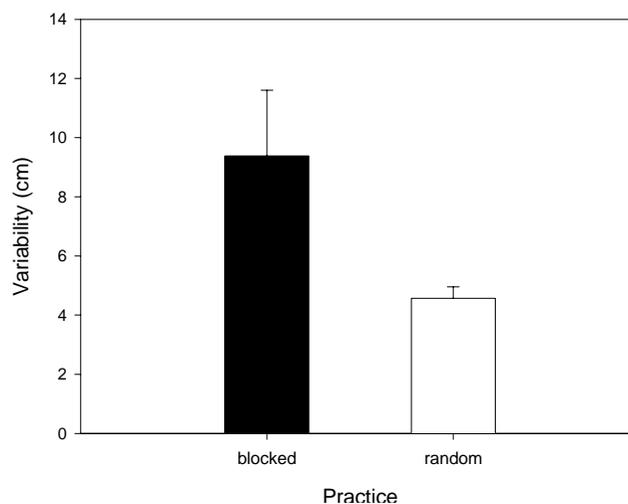


Figure 17. Amplitude variability of the DS in the x -dimension for blocked and random practice for the transfer phase.

Amplitude variability: y-dimension. The one-way (Practice: blocked, random) ANOVA for amplitude variability was not significant.

Amplitude variability: z-dimension. The one-way (Practice: blocked, random) ANOVA for amplitude variability indicated a significant main effect of practice, $F(1, 22) = 5.88, p < .05$. Random practice participants ($M = .98$ cm, $SEM = .09$ cm) had significantly smaller variability than blocked practice participants ($M = 1.61$ cm, $SEM = .25$ cm).

Mean movement time. The one-way (Practice: blocked, random) ANOVA for mean movement time was not significant.

Movement time variability. The one-way (Practice: blocked, random) ANOVA for movement time variability was not significant.

Impact Characteristics: Impact Velocity

Mean impact velocity. The one-way (Practice: blocked, random) ANOVA for mean impact velocity was not significant.

Impact velocity variability. Figure 18 displays variability of impact velocity for blocked and random practice for the transfer phase. The one-way (Practice: blocked, random) ANOVA for impact velocity variability indicated a significant main effect of practice, $F(1, 22) = 6.27, p < .05$. Random practice participants ($M = 5$ cm/sec, $SEM = .49$ cm/sec) had significantly smaller variability than blocked practice participants ($M = 8$ cm/sec, $SEM = .71$ cm/sec).

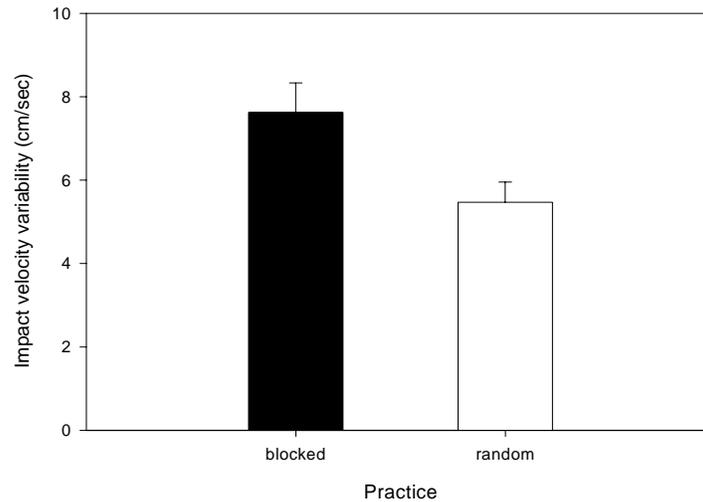


Figure 18. Variability of impact velocity for blocked and random practice for the transfer phase.

Impact Characteristics: Putter Position

Z-dimension: mean. The one-way (Practice: blocked, random) ANOVA for mean putter position was not significant.

Z-dimension: variability. Figure 19 shows variability of putter position for blocked and random practice for the transfer phase. The one-way (Practice: blocked, random) ANOVA for putter position variability indicated a significant main effect of practice, $F(1, 22) = 4.99, p < .05$. Random practice participants ($M = .33$ cm, $SEM = .02$ cm) had significantly smaller variability than blocked practice participants ($M = .51$ cm, $SEM = .08$ cm).

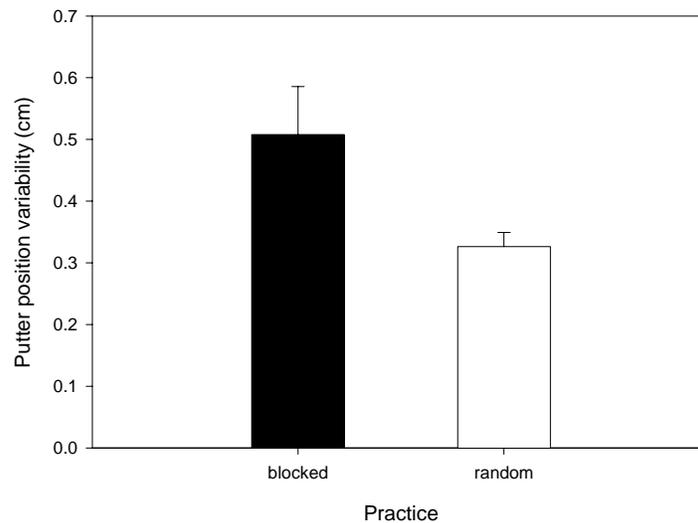


Figure 19. Variability of putter position for blocked and random practice for the transfer phase.

The random practice participants were not significantly different from the blocked practice participants on all dependent variables except BS amplitude variability in the z-dimension, DS amplitude variability in the x- and z-dimensions, impact velocity variability, and variability of putter position at impact. For these variables, the random practice condition showed significantly smaller variability compared to the blocked practice condition.

Results: Part Two

Stimulated Recall Interviews

Content analyses of the interview transcripts yielded three emergent categories: (a) participant focus, (b) self-evaluation of performance, and (c) benefits of practice. Each category included several subcategories, each of which is discussed below.

Participant Focus

Responses revealed that participants concentrated on several key elements of the putting stroke during the task. These elements were classified into three identifiable subcategories: target location, swing in general, and characteristics of club movement.

Target location. There were three targets (4 ft, 8 ft, and 12 ft) on Day One and four targets (4 ft, 8 ft, 12 ft, and 10 ft) on Day Two. Comments focusing on target location included descriptions about the target, the difficulty of different targets, and the new 10-foot target. Participants described the three targets either by colors (yellow, white, and orange) or by distance (short, middle, and long). They also described their task as stopping the ball on the target, in front of the target, or parallel to the target.

The level of difficulty for each target differed across participants. Paul said the first target (4 ft) was “the most difficult,” while Steve said it was “the easiest.” Steve felt the first target was easiest because it was the closest. Paul thought the first target was the most difficult because he felt the putting surface was fast and the target was too close. He noted that he just needed to “barely tap” the ball to the first target and it was really hard to leave the ball short. Linda said, “I think it was the last one [target]. It was the hardest one because it [the last target] seemed like it was so much farther than the first one.” Frank also felt the last target was the most difficult. He commented, “I don’t know why, it just was.”

When the 10 ft target was added on Day Two, opinions varied among the participants. Generally, the blocked group felt putting was more difficult than the random group. Paul, in the blocked group, felt “awkward” because he had not practiced

from this distance the previous day, causing him to feel uncomfortable. Participants in the random group, however, felt differently even though they too had not previously practiced from this distance. For example, Steve said “I was remembering how hard I was hitting it to the middle one [target], and then trying to hit a bit harder each time.” Linda also applied her previous experience to putt to the new target. Her earlier attempts at the 8 ft target were consistently long by about two feet. So when the new target (10 ft) was added, she felt like “I already knew how to hit that one.”

Swing in general. This sub-category captured the putting movement as a whole and identified the backswing as a specific component of the stroke. Both groups concentrated on maintaining a consistent stroke. Paul stated he was “just trying to do the same thing each time.” Linda thought she “was pretty consistent.” While both groups spoke about consistency, only the blocked group expressed concern about control. Frank wanted to “get control” while Paul stated “you have better control or you won’t even get close on the longer ones [targets].”

The backswing movement is how far the putter initially moved back and then forward to hit the ball. Participants tried to make the swing smooth and to keep the putter head as still as possible. They thought changing their backswing would determine the distance the ball would travel. Linda spoke of “bringing [the putter] back a little further to make it go longer.”

Since Paul and Frank [the blocked group] hit continuously to the same target, they tended to bring the club back the same amount each time. Steve and Linda [the random group], however, noted that adjustments to their backswing movement were

needed since the target distance changed on every attempt. This was particularly evident in Steve's third set of trials. At first he "didn't take it back, that's it. Everything is the same except the backswing...the length of the backswing." Linda, on her first set of trials, commented how she "was just trying to think how far to bring [the putter] back."

Characteristics of Club Movement. Here participants talked about the amplitude (distance of club movement) and force (velocity at impact) of the putter movement. Examples included hitting the ball too hard/soft, moving the putter too far/short as well as being consistent and making adjustments. Overwhelmingly, members from both groups commented about applying too much force along with moving the club too far. Steve, during his middle set of trials, commented that "I took it [putter] back too far [and] was too strong." Then again during his last set, he repeated "I still think I took that back way too far." Similarly during his first set of attempts on day two, Paul observed "I am just hitting them [putts] all too hard." Conversely, members also noted occasions when they did not apply enough force and/or amplitude. Frank, for example, commented he "hit it softly" during his second set of trials on Day Two. Correspondingly, Linda concluded, "I think I wasn't bring[ing] it back far enough."

Another common characteristic noted by both groups was a desire to attain consistency in the amplitude of club movement. In addition to applying too much force, Paul also commented that he needed to "...bring it [putter] back the same amount each time." Steve, too, realized the importance of "taking [it] back a certain distance."

Adjustment was a characteristic on which responses from the two groups differed. The random group appeared to have more difficulty adjusting their putter movement

than the blocked group on Day One. When asked how he might compensate for his mistakes on each trial, Steve concluded, “I guess I started realizing that, I don’t know, you need to adjust for that [different distance] better.” Conversely, Frank noted by Day Two that “I think I made the adjustment.” Both group’s adjustments were influenced by the previous trial. Frank, in the blocked group, stated “I hit one too hard, and I hit one too soft, so I hit right in the middle of that.” Because the target distance changed with each attempt, the random group’s adjustments appeared to be less accurate. For example, after putting to the farthest target, they usually putted past the closest target. Linda said, “I would do that [hit long to the short target after attempting a long putt] every once in a while.” Steve expressed the same outcome, “like if you hit a white ball [middle target] too long, the next time you leave it [the putt] short.”

Self-evaluation of Performance

In this second emergent category, participants evaluated their performance based on how and why they were successful and whether or not they were improving. This category involved five identifiable subcategories: expression of performance, thinking/concentration, end product, consistency, and kinesthetic feel.

Expression of performance. Participants evaluated their performance as being positive/improving, negative, and/or undecided. For the most part, all participants thought they were successful and showed improvement on both days. Paul and Frank, from the blocked group, commented that they were getting better after the first 12 trials and continued to improve during the second 12 trials. Paul said, “I think it [the next 12 putts] was getting better than the first 12.” They expressed they were “pretty successful”

and “improving” throughout the 36 trials. Frank said, “I think I did better that last round, than the first 12” and summarized, “Overall I think it was pretty successful, at all 36.” Similarly Steve, in the random group, also described his performance as being “pretty successful” in the early trial. Linda, too, felt she got better, and noted that, “I am kind of happy about that [putting straight], and none went off the end.”

The positive remarks continued on through to the end of Day Two’s trials. Paul said “I think I’m getting better and better each time.” Linda felt she was doing better and explained “well, compared to the first one [early trials] a lot better.” On Day Two, both groups said they were more successful than Day One. Frank commented “I think it was better than yesterday. I was more accurate today.” Steve thought he was improving because of previous practice and he added, “I think I did a good job, a 10 [on a 10-point scale].”

While the participants felt positive about their performance and improvement, they also expressed some concerns. Steve felt he was not improving or his performance remained the same in the early trials on Day One. Linda also thought she “totally messed up” on many of her putts. While Paul expressed trouble with putting on Day One, he believed his performance worsened on Day Two. He said, “I should have got better, but I may have got worse at this distance.” Frank, on the other hand, thought his performance remained the same at the end of Day One’s trials. Even on Day Two, he had mixed thoughts about his performance as noted in his comment “I don’t think it [hitting middle target] was any better.”

Although all participants evaluated their performance in both positive and negative terms at some point, three of the four expressed uncertainty about their improvement. Linda, Paul, and Frank simply responded “I don’t know” when asked if they were improving. These comments occurred across both days regardless of the set of trials being evaluated.

When asked to explain why their performance improved or not, four subcategories emerged. Rationales included thinking/concentration, end product, consistency, and kinesthetic feel.

Thinking/concentration. In this subcategory, participants expressed differing levels of cognitive processing about their putting task. Paul and Frank, for example, tried to “just concentrate more” to perform better particularly when the target distance changed. Paul admitted he did not think a lot, he “just hit it.” Frank, on the other hand, thought his concentration was “a bit up” on Day Two. He noted, “it is easier to concentrate on 30 [putts] than 130. You kind of lose concentration when you have so many of them.” Steve’s explanation was that he just “figured out” how to hit the ball to the first target.

Of the four participants, Linda’s thought processes were particularly evident across the two days of trials. On Day One, Linda’s lack of putting knowledge surfaced as she “was just trying to figure it [the putting motion] out” and struggled to determine “what makes it better of a hit.” The constantly changing target distances appeared to influence her thinking. For example, she commented that the last target “seemed like it was the hardest to think about because it seemed like a lot more thought went into [it].”

She further explained that her thinking on Day One “changed throughout the whole thing.”

By Day Two, Linda provides evidence of her application of knowledge acquired from Day One’s trials. She explained, “For the other one [Day One’s practice], I was trying to figure out [all the steps of the putt] every time.” By the second set of Day Two’s trials, Linda now realized she “already knew the motion of it.” On Day One, Linda felt rushed as she tried to remember the parts of the stroke. But by her final set of trials on Day Two, she acquired the fundamentals of the putting motion and felt this saved time because she did not have “to think about the whole putt again.”

End product. The participants used a variety of terms to express the results of each putt. They talked about their putts being too short, too long, or right on target. Linda commented, “like..they [the putts] were either going shorter or longer every time.” Paul and Frank putted short to the long target and long to the short target. Paul said, “On the short ones, I was long and on the long ones, I was short.” They worried about their putts going off the end of the putting platform and wanted to putt short for the long target. Frank observed, “I didn’t want that [hitting past the target and off the end of the platform] to happen. I didn’t want to hit it too hard to get it to go off the back of the thing. That is why I was hitting it short.” Steve’s overall assessment of the end product was “I’ve either been short, or right on.”

Consistency. Across both days, the participants tried to be consistent in their putting motion. Both Paul and Frank, for example, commented that they tried to hit the ball “the same way each time.” In his first 36 trials, Frank said, “you get the right

rhythm down” but by the 108th trial he noted “once again doing the same as on the first hole....just same old same old.” Linda, however, expressed she was “not very consistent” during her early practice trials. By Day One’s 108th trial she expressed some doubt when she said “I don’t know if I was more consistent towards the end.” However by her last set of trials on Day Two she concluded that she “was more consistent because you already knew how to hit it.”

Kinesthetic feel. The final rationale expressed by the participants dealt with how the putt “felt.” Paul attributed his success was due in part because he was able to get “the feel of it after each one.” Frank also mentioned, “I started to get the feeling down of how hard to hit it. I think that was why [I was improving].” Similarly on Day Two Linda added, “it just seemed like it [putting today] was more natural.” Paul had mixed reactions to his putting on Day Two. He said that overall “I feel more comfortable hitting it than yesterday.” When putting to the farthest target, for example, he felt “more comfortable on this one [target].” It was only when he hit to the middle target that he “couldn’t get a very good feel for it.”

Benefits of practice

The final emergent category reflected the participants’ thoughts about the effects of the repetitive putting trials on their performance. Responses primarily focused on the effects of the different practice schedules as well as the amount of practice involved in the trials. All participants identified the repetitive nature of the practice trials. Steve said, “It [practice trials] just kept going from first putt to second putt, and so on.” Paul and Linda commented their improvement resulted “just from practice.” Linda further

added, “Because of practicing, it [putting to the target] was easier” and that she wanted “more practice” to adjust to the varying distances. Frank mentioned at the end of Day One, “It [practice] could be effective”; but overall, practice was “just a long time.”

While they all thought practice helped to improve their performance, reactions about the practice schedules varied. Regardless of treatment group, several participants liked the blocked practice protocol. After taking “5 or 6 shots” Paul, in the blocked group, thought this mode of practice was “the easiest.” He said, “I think the more times you do it [putt to the same target], the more used to it you get.” Even though Steve was in the random group, he too liked putting repetitively to the same target. He said, “The same length is better because you can, like I said, get into a groove.” Linda also agreed and concluded, “If you’re hitting them all to the same target you just would’ve, like, found the rhythm and then they would get easier.”

Three of four participants also talked about the benefits of the random practice protocol. Although Frank was not a member of the random treatment group, he could see the benefits of having to make frequent adjustments to differing targets. He commented, “It [putting to different target every time] gives you more of a focus because sometimes you get tired of hitting to the same hole.” Steve added random practice helped him “judge” the differing distances between the targets. Linda also realized the benefits of random practice on Day Two after the blocked protocol post test. She said, “. . . . and now all you had to think about was the little adjustments whereas yesterday you had to think about the whole thing. I think, actually it [yesterday’s practice] made you remember it more.”

Along acknowledging the benefits of practice, the participants also identified drawbacks about each practice schedule. When asked whether putting repetitively to the same target was beneficial, Frank responded “well, not 36 times in a row.” Paul, also from the blocked group, summed up his experience as being “bored” and added that “I don’t putt that too many when you are really playing.” Frank agreed that he was “tired” of hitting to the same target and commented “when it is time to change, it is hard to make that adjustment.” Members of the random group also alluded to drawbacks associated with their protocol. Steve noted that the randomness of the trials made it “more difficult” to judge his backswing. Having to constantly adjust to the differing targets, Linda admitted that she “got kind of tired.” Like Steve, she also agreed it was difficult to adjust when the target distance changed every time.

In sum, content analyses resulted in three emergent categories: (a) participant focus, (b) self-evaluation of performance, and (c) benefits of practice. Specifically, participants thought about the target location, their swing in general, and the characteristics of their putting movement. Evaluation of performance was described in terms of perceived success and improvement. Finally, members of both groups identified strengths and drawbacks of their practice protocols.

Discussion

The first purpose of this study was to offer further insight into the role of introducing contextual interference (CI) into the practice environment. In addition to verifying the utility of a high CI practice schedule for improving outcome performance of the putting action, we examined whether the extent of CI experienced during practice

had a concomitant impact on the kinematics of the putting action. This latter purpose was accomplished by examining how the learner's practice condition accommodated the acquisition of previously defined kinematic characteristics of an expert's putting action. Finally, little is known about the participants' cognitions under different practice conditions. Stimulated recall interview data were assessed during this experiment to analyze the thought processes of blocked and random practice individuals. Each of the primary objectives mentioned are addressed separately in the following sections: (a) Utility of high CI practice: Beyond outcome measures, (b) The characteristics of the kinematic changes in golf putting action during practice, (c) Cognitions of participants during various stages of practice, and (d) Implications for future research.

Utility of High CI Practice: Beyond Outcome Measures

In this study the global error data were consistent with data addressed in previous CI studies (Brady, 1998; Magill & Hall, 1990). Overall, acquisition performance was poorer for those individuals practiced in the random format compared to their blocked practice counterparts. Nonetheless, following a 24-hour delay, both retention and transfer performance was superior for those individuals in a high CI schedule (i.e., random practice). These data add to the growing number of examples from applied settings in both athletic (Landin & Hebert, 1997) and professional (Hall et al., 1994) environments supporting the use of high CI during practice as a useful method for enhancing skill acquisition.

The present data go beyond merely demonstrating the utility of high CI practice protocols with respect to assessing outcome measures. We also wanted to examine the

changes in the movement kinematics of the learners assigned to blocked and random practice schedules in order to identify particular aspects of the movements that may be differentially impacted by the different practice methods. Probably the most important initial observation was the finding that the general approach used by both blocked and random participants was remarkably similar. For example, Delay et al. referred to the isochrony principle in which the performer increased the amplitude of the downswing (DS) but maintained the movement time of the DS in order to increase club velocity at impact to propel the ball over a greater distance. Both blocked and random practice participants followed this principle in their attempts to differentiate between putts of greater distance. Delay et al. also reported that while novice golfers attempted to maintain some symmetry with respect to the impact during the DS amplitude (i.e., impact occurred at about the midpoint of the DS amplitude), experts tended to strike the ball at approximately one third of the DS amplitude that led to a more exaggerated follow-through. The participants in the present study mimicked the performance of the experts in this regard. This finding was true for both the random and blocked participants.

While some general strategies used by the participants from the two practice schedules were similar, there were differences in the kinematics between them. Interestingly, these differences were not revealed in the mean performance of any of the kinematic variables. The differences in the kinematics between both groups were only evident in variability. During acquisition, the random practice participants appeared to have greater difficulty consistently reproducing the amplitude in the x -dimension. This

was particularly notable when putting to the farther target distances. Also noted was the larger variability in both impact velocity and putter position at impact (z -dimension) when putting to the farther target distances.

The results were quite different during both retention and transfer. Again, individuals from the different practice schedules differed with respect to variability in producing particular movement kinematics. These data were almost the reverse of those reported during the acquisition phase. Variability in the amplitude in the x -dimension for the DS was statistically lower for the random practice members. Furthermore, this was accompanied by reduced variability in the putter position at impact resulting in less variability in impact velocity. In summary, it seems that the apparent advantage of putting accuracy for the blocked practice is coupled with lower variability in the specific characteristics of the putting action. The kinematic characteristics that appeared to have been well established with the blocked practice during acquisition turned out to be the least resilient during retention and transfer phases.

Implications for contemporary theories of CI. These data, while having a direct implication for the practice schedules of the golf putting action, have some important ramifications for contemporary theoretical descriptions of the CI effect (Immink & Wright, 2001; Lee & Magill, 1983; Shea & Zimny, 1983; 1988). While the veracity of the CI effect is rarely questioned, the underlying theoretical basis for its emergence is not well understood. Following Shea and Morgan's (1979) demonstration of this effect, two distinct theoretical descriptions have driven most of the subsequent experimental endeavors.

The elaboration hypothesis forwarded by Shea and Zimny (1983; 1988) places heavy emphasis on the improvement in the organization and richness of the long-term memory structures that result from random rather than blocked practice. One question from this perspective is whether or not the memory resulting from random practice is qualitatively different than that formed following blocked practice. Recent work suggests that the formation of the memorial representations follows a similar path, but the speed at which the memory is formed is considerably quicker following random practice.

Wright, Magnuson, and Verwey (2003) demonstrated that both blocked and random practice participants used segmentation driven by the development of motor chunks as a fundamental process by which sequential movements are controlled and executed following extended practice. However, the cost (i.e., latency) of executing such movements is considerably less (i.e., more efficient) for random-practiced individuals both in terms of the pre-programming costs (i.e., pre-planning before movement initiation) and concatenation costs (i.e., packaging the movement segments of longer sequences together as the movement unfolds). Congruent with these recent observations, the data from the present study reveal a number of examples in which the unfolding of the movement follows a similar course for both blocked and random individuals even when alternatives are available.

One aspect of the results from the present study suggests that maybe there is some fundamental way in which information about a learned movement is stored in memory following random or blocked practice. Specifically, Chamberlin and Magill

(1992a, 1992b) described schema abstraction and an exemplar-based memory model. A prediction of schema abstraction would be that all novel exemplars should be performed equally well and more importantly as well as those tasks practiced during acquisition phase. Alternatively, an exemplar-based model would predict differing amounts of error in performing novel responses. More importantly, the extent of error should be dependent on how similar the novel task is to a practiced response. The mean global error results in retention and transfer phases showed that random practice is consistent with schema abstraction model prediction while blocked practice is consistent with exemplar-based model.

A different explanation for the CI effect was offered by Lee and Magill (1985) under the rubric of the reconstruction hypothesis. The reconstruction hypothesis focuses on the utility of random practice for improving the fluency of the processes used in working memory in order to efficiently plan an upcoming movement. In recent years there have been a number of demonstrations that random practice does indeed facilitate working memory operations with significant improvements occurring in the response programming (Immink & Wright, 2001; Wright, Black, Immink, Brueckner, & Magnuson, in press) but not response selection stage (Wright et al., 2003).

In the present study, as noted earlier, it appeared that both blocked and random practice participants took advantage of similar strategies such as the isochrony principle (Delay et al., 1997) presumably to reduce the demands on response programming as they attempted to make attempts to reveal some initial improvements. It should be noted however that the improvements in the motor programming processes identified in the

aforementioned studies were the result of practice bouts that were more extensive than those used in the present study. It is also interesting to note that while quantitative indicators alluded to adoption of similar strategies, the participants expressed no conscious use during their practice trials.

The Characteristics of The Kinematic Changes in Golf Putting Action during Practice

The second purpose of this study was to examine how the kinematic parameters of the golf putt such as the amplitude of the BS and DS movement, movement time of both BS and DS, impact velocity, as well as the putter position at impact changed with practice. While there has been some detailing of the differences in the kinematic profile of expert and novice putters (Delay et al., 1997; Paradisis & Rees, 2002), these previous efforts focused on 2-dimensional descriptions rather than the 3-dimensional approach used in this study. Moreover, their descriptions focused primarily on the mean performance (i.e., mean amplitude in the x -dimension) while the present work offered a detailed evaluation of the changes in performance variability for each kinematic parameter with practice. Addressing this additional dimension, in particular the variability of the position of the putter at impact (i.e., z -dimension), provided important elaboration of the earlier work reported by Delay et al. (1997).

There were also data congruent with data reported by Delay et al. Specifically, there was an increase in amplitude in the BS and DS components, for both x and y dimensions with increasing distance of the targets during practice and retention phases. A new finding from the present study was the case for movement in the z -dimension – the plane perpendicular to the line of the putter toward the target. Additionally,

movement time of the BS also increased as the target distances increased but movement time of the DS remained unchanged. As a result, the velocity at impact also increased with increasing distance to the target.

Delay et al. reported symmetry in the DS movement for novice performance in that impact occurred at approximately one-half of the total amplitude of the DS in the x -dimension. On the other hand experts had the tendency to hit the ball at approximately one-third of the amplitude of DS. In the present study, performance of the individuals in both practice schedules was more like that of the experts in Delay's study. These results run contrary to Delay's study and though these participants were classified as novices, they were not regular golf participants. Nonetheless, the task demands in this experiment were fairly low as evidenced by the relatively low global error even after only 108 trials of practice.

Cognitions of Participants during Various Stages of Practice

The final purpose of this study was to investigate the participants' thought process during task performance. Results of the participant interviews provided evidence of consistent, reflective thought processes as well as notable differences between the two groups (Shea & Zimny, 1983; Simon & Bjork, 2001). Although both groups remained focused on their tasks, the strategies they applied were different during practice. Paul and Frank, in the blocked group, were more concerned about controlling the ball, (i.e., accuracy) and showed more consistency in the early trials of practice. They "just hit" the ball and felt comfortable putting repeatedly to the same target. Statistical analyses of mean global error revealed the blocked group did indeed putt more

accurately than the random group. Because the random group was exposed to multiple tasks, the task difficulty level was perceived to be greater. Steve and Linda, for example, tried to adjust their club movement, but their adjustments were not as accurate as the blocked group due to the changing target distances.

However, since participants in the random group had more opportunities for inter-item processing and thus more opportunities for task comparisons, there were more opportunities for thinking elaborately about the tasks (Wright, 1991). Linda, in the random group tried to “remember how [I] hit specifically to the orange one [12 ft distance]” and “then to the yellow one [4 ft distance].” This kind of inter-item processing may have accounted for why the random group performed better on the retention and transfer tests on Day two.

According to CI theory, blocked practice conditions lead to impoverished encoding and thus poorer performances in post-testing (Brady, 1998). Under the post testing conditions, members of the blocked group both expressed dissatisfaction with their performances. Paul, for example, said, “I should have got better, but.....” while Frank commented, “I don’t think it was any better.” The mean global error revealed less accurate performances from the blocked group members on the post-test and provided performance data that supported their comments.

Because of the nature of practice, Paul and Frank, in the blocked group, tried to hit the ball “the same way each time” which may have accounted for their lack of success putting to the new target during post-testing. Steve and Linda, in the random group, were “not very consistent” with their putter movement on Day One. However, on

Day Two, comments about their putting movements changed. Paul now felt “awkward” trying to hit the new 10-foot target while Linda felt more comfortable because she “already knew the motion” of putting. Statistical analyses revealed that on Day One variability in BS and DS movement and impact velocity for the blocked practice participants were significantly smaller than those of the random practice participants. The random practice participants, on the other hand, had significantly smaller variability on those variables during the retention and transfer tests.

All participants knew that changing their backswing movement and impact velocity would determine the distance the ball would travel. “Bringing” [the putter] back “a little more” and trying to “hit [the ball] harder” made the ball travel farther. Statistical analyses confirmed that both groups significantly increased BS movement and impact velocity as the target distance increased. As Delay et al. reported, the larger the amplitude of the BS, the larger the amplitude of DS movement between the end-point of BS and the ball occur. As a result, the velocity of the club while traveling this larger DS amplitude would be higher if the club was moved within the same time.

As noted earlier, no participants mentioned or indicated that they were consciously aware of amplitude of the DS movement and movement time. Statistical analyses showed that while both groups increased the amplitude of DS movement as the target distance increased, their DS movement time remained the same. Therefore, impact velocity would be proportional to its DS amplitude. Consistent with the isochrony principle, this in turn facilitates programming of the movement regardless of the participants’ level of expertise (Delay et al, 1997). Numerous other studies (Green &

Flowers, 1991; Liao & Masters, 2001; Masters, 2000; Magill, 1998; Maxwell, Masters, & Eves, 2000) also report that participants can acquire motor skills/knowledge without using conscious strategies.

The results of the interview data also showed how these golfers tried to actively process information despite receiving little instruction. Steve and Paul noted that “the surface was fast” after a few trials, while Frank “anticipate[d] the extra roll.” When faced with new problems (i.e., new 10 ft target), the random practice members, Steve and Linda, were able to apply their previous experience (i.e., putting to different targets). All four individuals interacted with their putting environment (i.e., putting surface/ target locations) and appeared to gain an understanding of its characteristics (i.e, fast putting surface/ new target). Each tried to find his/her own solution to the challenges presented in their putting tasks (i.e, “just tap” the ball/using previous knowledge). By matching new information with information gained from previous experience, they were able to establish meaningful connections when problem solving.

Since different practice schedules result in different levels of cognitive processing (Blandin, Proteau, & Alain, 1994), learning of skill may be impacted. Prawat (1992) stated that learning occurs best when students are actively engaged in cognitive processing and are responsible for their own cognitive efforts, actions, and consequences. This study’s results appear to support Chen’s (2001) recommendation that instructors might want to encourage students to be initiative thinkers and creative problem solvers by having them generate ideas, draw conclusions, and analyze, evaluate, and reflect on

their learning responses. One way to encourage such thinking is through task structures that challenge students both cognitively and psycho-motorically.

Blocked practice results in repetitive activities do not encourage and/or facilitate in depth thoughtful decision-making. Random practice situations, however, help individuals retain learned skills longer and to apply these learned skills to new tasks. Li and Wright (2000) believe this retention and transfer to new skills occurs because random practice increases the extensiveness of the retrieval routes available. The interview results showed that the blocked practice members felt the task was “easier,” but they did not like the repetitive nature of the task. Although the random schedule was “more difficult,” it helped Steve and Linda “judge” the different distances and made them “think” more about the task.

Since learning efficiency is based on a student’s information processing ability (Guadagnoli et al., 1999), teachers might want to consider the level of the performer. Lee (1997) suggested that if students are required to perform tasks that are too challenging or not challenging enough, their level of engagement will be affected in a negative manner. Although we make no attempt to generalize beyond the immediate population, in a teaching/learning environment, these novice golfers might begin under the blocked schedule conditions at the early stages of practice and then switch to a random schedule for retention of the learned skill for later use. Previous studies reported the benefit of this progression from blocked practice to random in both rifle shooting (Boyce & Del Rey, 1990) and golf putting (Guadagnoli et al., 1999). Further study is

recommended to examine the utility of this approach as well as when and how blocked and random schedules might be switched in order to maximize learning.

Implications for Future Research

This study provides support for the utility of a random practice format for enhancing skill acquisition. Previous studies incorporated random practice to improve the execution of the pawlata roll in kayaking (Smith & Davies, 1995); batting performance in baseball (Hall et al., 1995) as well as serving in volleyball (French, Rink, & Werner, 1990) and badminton (Goode & Magill, 1986). Moreover, this practice protocol has been also used to encourage speech improvements for individuals with acquired onset of speech apraxia (Knock, Ballard, Robin, & Schmidt, 2000; Porretta, 1988; Porretta & O'Brien, 1991) and more precise execution of movements by trainee dentists (de Croock, van Merrienboer, & Paas, 1998). Finally, random practice seems to offer long-term learning benefits not only for typical individuals utilized in the aforementioned studies but also for individuals with a variety of disabilities (Painter, Inman, & Vincent, 1994). It appears safe to conclude that the value of this practice manipulation is quite robust and far reaching.

As noted earlier, however, not all learning is accompanied by a full understanding of the changes occurring in performance and, perhaps more importantly, the reasons underlying these changes. In this study we noted that no participant focused on or reflected about the putter position at impact. This kinematic variable is one that is most clearly associated with good putting performance and represents a parameter that undergoes considerable change across the acquisition and test phases.

These data are congruent with the ongoing dialogue addressing the role of conscious control of movement processes that is being entertained in the areas of implicit vs. explicit learning (Green & Flowers, 1991) and external vs. internal focus of attention (Wulf, Hoess, & Prinz, 1998). For example, on the z -dimension, little awareness of putter head changes that occurred was indicated by the learners. The question arises as to whether or not we should make the learner aware of the putter position at impact, thereby expediting possible improvement in this dimension. Or, should learning of this dimension occur at a level in which the learner is not consciously aware. These questions underscore the dilemma whereby instructions may actually hinder improvement (Green & Flowers, 1991) and have implications for the use and presentation of instructions and feedback in the learning process.

Finally, we would be remiss if we did not offer some suggestions for facilitating practice of the golf putt per se. It would appear that one aspect of the putting action that is important to consider in the initial stage of practice is the extent of movement of the putter in the z -dimension. This is crucial for the positioning of the putter at the time of impact. A great deal more variability occurred in this component of the action than within the other recorded movement dimensions (i.e., x - and y -dimensions). Thus, it would appear that any pedagogical intervention should include some attention to this aspect of putting.

In that regard and of particular interest to the pedagogist was the finding that the extent of variation in the putter position at impact (i.e., z -dimension) was different for individuals that practiced within different schedules. Specifically, exposing an

individual to random practice resulted in greater reduction in variability in the putter position at impact based on retention and transfer phases. Future research might expand the sample size and practice schedules (i.e., blocked, random, and blocked/random combined) with/without the instruction to examine if different practice schedules affect participants' performance whether or not they are aware of their kinematic movements like putter position at impact.

CHAPTER III

CONCLUSIONS

Based on the results of the present study, the following conclusions were reached:

1. This study was congruent with the current CI literature. Random practice participants were poorer in performance during practice compared to their blocked practice counterparts. However, the individuals exposed to a high CI schedule exhibited superior performance during the retention and transfer phases.

2. With respect to the kinematics, individuals placed in high and low CI practice schedules could be differentiated primarily on the basis of performance variability. Specifically, random practice individuals appeared to have greater difficulty consistently reproducing the amplitude in the x -dimension, impact velocity, and putter position at impact (z -dimension) during practice. This phenomenon was reversed during the retention and transfer phases. Variability of those variables was reliably lower for the participants assigned to random practice during retention and transfer trials.

3. Data from this study revealed the importance of the z -dimension in golf putting. That is, the putter position at impact was clearly associated with more successful putting performance. Moreover, this kinematic parameter underwent considerable change across the practice and test phases.

4. This study provided insight into and information about the participants' thought processes during the performance of a motor task. Expressions about their performance and putter movements supported the statistical analyses. The participants

actively learned the putting task while receiving little instruction. Their cognitions under the different practice conditions have potential implications for educators during the acquisition of motor skills.

5. Some of the more distinct changes that occurred in the movement kinematics (i.e., in the z -dimension) were not indicated by the participants. This suggests that not all learning is necessarily accompanied by a full understanding of the changes that occur in performance.

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APPENDIX A

THE DATA ANALYSIS PROGRAM

```

clear all
initial0=[19.1446 -254.0933]; %initial right point
initial1=[-22.3894 -235.6672]; %initial left point
initial_imsi=[initial1(1,1) initial0(1,2)];
cos_imsi=norm(initial_imsi-initial0,'fro')/norm(initial1-initial0,'fro');
sin_imsi=norm(initial_imsi-initial1,'fro')/norm(initial1-initial0,'fro');
rotation=[cos_imsi sin_imsi;-sin_imsi cos_imsi];

disp('Data directory is C:\Work\Hwang Pro\golf dissertation\putt ');

% Test Subject input
sub_no = input('Input subject number: ');

% Trial number input
tr_bgn = input('Enter the trial number to begin with: ');
tr_fin = input('Enter the trial number to finish: ');

f_bgn=size(num2str(tr_bgn)); % check the number of digits of tr_bgn
k=1;

% Load data file for analysis.
N = tr_fin - tr_bgn + 1;
for tr=1:N
    f_fin=size(num2str(tr_bgn+tr-1)); % check the number of digits
    if f_fin(2)>f_bgn(2) % if the number of digits is bigger than the number of digits of tr_bgn
        fname1(k,:)= ['C:\Work\Hwang Pro\golf
dissertation\putt\p',num2str(sub_no),'_xyz_', 'putt','t',num2str(tr_bgn+tr-1)];
        load (fname1(k,:));
        k=k+1;
    else
        fname(tr,:)= ['C:\Work\Hwang Pro\golf
dissertation\putt\p',num2str(sub_no),'_xyz_', 'putt','t',num2str(tr_bgn+tr-1)];
        load (fname(tr,:));
    end,

% colldate    collection date
% numbaxis    number of axis = 3 i.e. (X,Y, Z)
% numbfam     number of frames = samples/second * total sampling time [second]
% numbleds    number of measurement points
% trialname    trial name
% trialtype    3D data file
% txyz        time data
% xyzdata     xyz data
% xyzsamp     samples/second

put_x(:,tr) = xyzdata(:,1);
put_y(:,tr) = xyzdata(:,2);
put_z(:,tr) = xyzdata(:,3);

```

```

%-----%
% Find Data Extraction Points from the Putter Movement in X-axis
%-----%

% find putting finish point (x-axis) %
[put_fin(tr), put_fin_ind(tr)] = min(put_x(:,tr));

% finish point data & index
% find putting start and max backswing points (x-axis) %
[put_xmax(tr), put_xmax_ind(tr)] = max(put_x(1:put_fin_ind(tr),tr)); % max backswing point data &
index
[put_strt(tr), put_strt_ind(tr)] = min(put_x(1:put_xmax_ind(tr),tr)); % starting point data & index

end,

%-----%
% Displacement of Putter
%-----%

% backswing displacement (x-axis) = max backswing point - starting point%
put_x_bk = put_xmax - put_strt;

% downswing displacement (x-axis) = max backswing point - finish point %
put_x_dn = put_xmax - put_fin;

for tr=1:N
% backswing displacement (y-axis) = max backswing point - starting point%
put_y_bk(tr) = put_y(put_xmax_ind(tr),tr) - put_y(put_strt_ind(tr),tr);

% downswing displacement (y-axis) = max backswing point - finish point %
put_y_dn(tr) = put_y(put_xmax_ind(tr),tr) - put_y(put_fin_ind(tr),tr);

% backswing displacement (z-axis) = max backswing point - starting point%
put_z_bk(tr) = put_z(put_xmax_ind(tr),tr) - put_z(put_strt_ind(tr),tr);

% downswing displacement (z-axis) = max backswing point - finish point %
put_z_dn(tr) = put_z(put_xmax_ind(tr),tr) - put_z(put_fin_ind(tr),tr);

%-----%
% Impact Velocity of the Putter
%-----%

% find the same point in the swing as the starting point %
diff_x(:,tr) = abs(put_x(:,tr) - put_strt(tr));
[diff_min(tr), diff_ind(tr)] = min(diff_x(put_xmax_ind(tr):put_fin_ind(tr),tr));

% velocity = ((starting position - (1 index)) - (starting position + (1 index))) / (2 sample time)
x_vel(tr) = abs(put_x(put_xmax_ind(tr)+diff_ind(tr)-1,tr) - put_x(put_xmax_ind(tr)+diff_ind(tr)+1,tr)) /
(2/xyzsamp);

end,

```

```

fname
if f_fin(2)>f_bgn(2)
fname1
end,

put_x_bk
put_x_dn
put_y_bk
put_y_dn
put_z_bk
put_z_dn

x_vel

%-----%
% Movement Time of the Putting
%-----%

% backswing time; xyzsamp=samples/second %
t_bk = (put_xmax_ind - put_strt_ind) / xyzsamp

% downswing time; xyzsamp=samples/second %
t_dn = (put_fin_ind - put_xmax_ind) / xyzsamp

% total swing time; start to finish %
t_tot = (put_fin_ind - put_strt_ind) / xyzsamp

final(:,1)=-put_x_bk';
final(:,2)=put_x_dn';
final(:,3)=-put_y_bk';
final(:,4)=put_y_dn';
final(:,5)=-put_z_bk';
final(:,6)=put_z_dn';

final(:,7)=x_vel';
final(:,8)=t_bk';
final(:,9)=t_dn';
final(:,10)=t_tot';

final(:,11)=put_diss_impact1_x;
final(:,12)=put_diss_impact1_y;
final(:,13)=put_diss_impact1_z;

final

```

APPENDIX B

INFORMED CONSENT FORM

INFORMED CONSENT

Title: An examination of the impact of introducing greater contextual interference during practice on learning to golf putt

I understand that Gyu-Young Hwang, an Ed.D. Candidate in the Department of Health and Kinesiology, is conducting an experiment to examine how different practice procedures impact the display of particular movement forms during golf putting.

I understand I will be one of twenty four individuals participating in this experiment. I understand that I will be required to visit the Human Performance Laboratory in the Department of Health and Kinesiology at Texas A&M University on two separate occasions. During my first visit (approximately 1.5 hours), I will be required to attach infrared light-emitting diodes (IRED) on my head and shoulders and perform golf putts to three different targets. I understand that I will then be required to return to the Human Performance Laboratory approximately 24 hours later. The same procedure will be repeated with the exception that the number of putts will be reduced (for about 1 hour). I also understand I may be asked to have my performance videotaped and be interviewed immediately after my performance. I understand the interview will be audiotaped and then transcribed. Questions during the interview will focus on what I was thinking about during my golf putting attempts. I have also been informed that the recorded video and audio tapes will be destroyed by May 31, 2004.

I agree to be videotaped, audiotaped, and interviewed.

I do not agree to be videotaped, audiotaped, and/or interviewed. However, I will continue to participate this experiment.

I understand that during these visits there is a small risk that I may experience fatigue in my shoulders, back, and/or arms due to the prolonged golf putting activity. Should this occur I have been told that I may request the opportunity to rest at any time during the experiment in order to allow such fatigue to dissipate. I understand that no medical treatment will be provided if injury should occur.

I understand I will receive one experimental credit toward the experiment requirement in KINE 406 if I complete this experiment. I may withdraw from this experiment at any time but should I withdraw from the experiment, I will not receive the aforementioned credit toward my Kinesiology class.

I understand that data obtained regarding my participation in this experiment is confidential and the aforementioned data will be stored in a filing cabinet of the investigators' research advisor, Dr. Ron McBride.

I understand that this research study has been reviewed and approved by the Institutional Review Board-Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, I can contact the Institutional Review Board through Dr. Michael W. Buckley, Director of Support Services, Office of Vice President for Research at (979) 458-4067.

Initials: _____ Date: _____

I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

I have been given a copy of this consent form.

Participant Signature _____ Date _____

Principal Investigator Signature _____ Date _____

For more information regarding this study please contact Mr. Gyu-Young Hwang or Dr. Ron E. McBride at Dept of Kinesiology, Texas A&M University, College Station, TX 77843 or via phone at (979) 845-8788 or via e-mail at ghwang@hlkn.tamu.edu.

VITA

GYU-YOUNG HWANG

Degrees

D. V. M. in Veterinary Medicine	Seoul National University	1986
M. Ed. in Kinesiology	Texas A&M University	2001

Professional Experience

- Teaching golf professional, Lone Star Golf Academy, 1996-2003
- Certified Golf Coach Level III, National Association for Golf Coaches and Educators, 2003
- Member, Professional Golfer's Association of America, 1998

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