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An Investigation of the Testing Effect on Motor Learning

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AN INVESTIGATION OF THE TESTING EFFECT ON MOTOR LEARNING

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ABSTRACT

Optimization of learning processes is the goal many educators strive to achieve with their students. One of the potential methods used towards optimizing this process is what's known as the testing effect. The testing effect is the improved performance on a retention test as a result of prior testing during some period of practice. Previously, the testing effect was investigated using mostly cognitive tasks such as the learning of a number of words. In this paper, we examine the impact the testing effect has on learning the motor skill of putting. The study used a 2 x 2 mixed design, where the within-subjects factor had two levels of pre- and post-tests, and the between-subjects factor had two levels of practice and practice-test groups. A total of 24 participants were used in the study, all novice golfers (handicap 14+) who were asked to practice and learn a 10 foot putting task. The task was to be learned over 5 blocks of putting, where 15 putts per block were provided. Participants were randomly assigned to one of two groups: 1) Practice and 2) Practice-test, with the difference between groups being the perception of being tested or simply practicing. The primary dependent variables of interest were arousal level (salivary α-amylase), putting stroke kinematics (acceleration and face-to-path), and end point error (absolute error and variance). Results from the study revealed a significant main effect for Test $\underline{F}\ (1, 22) = 8.452$, $\underline{p} < .05$ looking at variance in the y-measure direction (i.e., long or short of the target) across pre- post-tests. Additionally, when looking at variance in the z-measure direction (composite of x and y measures) a significant main effect for Test $\underline{F}\ (1, 22) = 9.033$, $\underline{p} < .05$ was found. Although not statistically significant, a trend towards a significant Group x Test interaction $\underline{F}\ (4, 88) = 2.469$, $\underline{p} = .057$ was seen in the reduced variance across each of the 5 practice blocks. There were no significant results to report from the analyses examining the accuracy of putting. In conclusion, the testing effect did not produce results any different to that of the traditional practice method used in the study. This

suggests that for novice golfers, there are no added benefits of using testing during practice to improve their putting.

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I would like to dedicate my thesis project to two of the most important influences on my personal, sporting, and academic life. Both have taken time out of their personal lives to invest in me as a person, athlete, and now student. Along the way these men have shown me the value of working hard to achieve whatever it is I am after, and the importance of enjoying the process of working hard. I cannot thank either enough for the patience they have shown me through the failures I have made, using these as a chance to educate and guide me towards being a better person and student. Finally, I would like to thank both of these men for the friendships we have made over the years, which will continue for many great years to come! Although there is no way I can possibly repay what was done for me, one day down the road I want to pass this guidance, patience, and friendship onto another young adult in need, just like me.

Thanks Chris and Mark.

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CHAPTER 1

INTRODUCTION

Educators from various realms, such as school teachers and sport coaches, are often faced with the challenge of development and application of effective methods towards optimizing the learning process. That is, what tools can educators use to present information to students in a manner that is comprehendible and what strategies can students apply to enhance their learning from the information? Optimization of the learning process is considered the holy grail among educators among a variety of fields, and is of great importance in today's society. One method towards optimizing this process, with support from a large body of literature, is known as the *testing effect*. The testing effect is the improved performance on a retention test due to prior testing during some period of practice (McDaniel, Roediger & McDermott, 2007). For example, a student is given a list of ten words to study for homework. The student studies the words for some period, and instead of re-studying the same words, is given a test on the ten words. Once the test is complete, the student continues re-studying the words, repeating the process of study periods followed by a test until the information is learned. These intermittent tests allow the learner to understand what he/she does and doesn't know, providing valuable information typically used to guide the next study session. Many studies have examined the testing effect using cognitive tasks such as word memorization (Hogan & Kintsch, 1971), paired-associate memory (Allen, Mahler & Estes, 1969), and reading comprehension (Roediger & Karpicke, 2006). However, few studies to date have applied this concept to the learning of a motor skill.

The main outcomes when using the testing effect in cognitive learning include a decrease in initial practice performance, greater performance on a delayed short-term retention test, followed by a significantly higher performance on a delayed long-term retention test (Carrier & Pashler, 1992). These results indicate that although initial practice performance suffers, delayed performance is improved alongside retaining the information for a greater duration of time (Roediger & Butler, 2011). While these studies show the positive effects testing can have on learning in the cognitive domain, the effects are still relatively unknown in the area of motor learning.

Preliminary data suggests the testing effect brings about similar results when acquiring a new motor skill, producing increased error during practice (Hagman, 1983), displaying faster initial acquisition of the skill during retention testing (Kromann, Jensen & Ringsted, 2009), and a longer retention of the learned movement skill (Adams & Dijkstra, 1966). Although some studies using the testing effect for long-term retention have found it beneficial, a recent study suggests otherwise (Boutin, Panzer, & Blandin, 2013). As such, the current paper will focus on the testing effect and the outcomes associated with it when learning a motor skill.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Testing Effect in Cognitive Tasks

For over half a century, the effects of intermittent testing have been examined using cognitive tasks such as memory of words (Belbin, 1950), free recall (Allen, Mahler & Estes, 1969; Carpenter & DeLosh, 2006), foreign language learning (Carrier & Pashler, 1992), face-name learning (Carpenter & DeLosh, 2005), definition learning (Cull, 2000), and general knowledge facts (McDaniel & Fisher, 1991). Over the past seventy-five years, the testing effect has demonstrated short-term effects that are empirically stable. An initial study done by Darley and Murdock (1971) examined the effects testing had on the free recall of words. The protocol required subject to learn words from ten different lists, each list containing twenty unrelated nouns, for which subjects were given five seconds to rehearse aloud each word on the list. Once the practice trial was complete, each subject was given either a written free recall test to recall as many words as possible, or instructed to count by three's for two minutes in an attempt to clear any words from the short-term memory (this time was selected based on the average time it took test takers to recall words). Each subject was tested on five word lists and untested on the other five, with no more than three tests occurring consecutively. Prior to the final recall test, all subjects were required to count backwards by twos for one minute to again eliminate the use of short-term memory during recall testing. During final testing, subjects were given a sheet of paper and no time restriction to recall as many words from the ten lists. What resulted was words that had been tested were recalled at a significantly higher rate than untested words. Additionally, a second study showed similar results in that when subjects were tested on their recall ability of general facts, those facts that appeared on a prior test were recalled at a significantly higher rate than untested facts (McDaniel

& Fisher, 1991). The results from these two studies suggest that testing is a beneficial strategy towards improving short-term recall ability of words or general facts.

Although the beneficial effects of testing for learning in the short-term are robust, the mechanism(s) explaining the outcomes are unknown. Two explanations have been offered attempting to detail the working mechanism behind the testing effect, with one such explanation coming from Darley and Murdock (1971). The researchers proposed the testing effect was due to the practice of memory retrieval experienced during testing, increasing item accessibility during a final retention test. The explanation suggests that by practicing retrieval through testing, one is better able to retrieve the information during a final retention test. It is not necessarily the case that study-test and study-only groups learn differently, rather testing increases the accessibility of said learned information (Darley & Murdock, 1971). A second possible explanation suggests that the combination of practice and testing provides greater encoding variability when compared to practice-only (McDaniel & Masson, 1991). The idea behind this explanation is that a memory representation with multiple different encodings is associated with a greater number of different retrieval routes, therefore making the memory representation more accessible than a representation with a single route. As one increases the number of retrieval routes to a specific bit of information, one also increases their accessibility to recall the targeted information through one of those retrieval routes (McDaniel & Masson, 1991). Practicing recall (or being tested) encodes additional routes of retrieval on top of those routes encoded during practice.

While the use of testing results in improved short-term acquisition of information, even more robust are the effects testing have on long-term retention. An original study by Allen, Mahler, and Estes (1969) examined the testing effect and its impact on long-term information retention.

The study used forty college aged men and women and provided them with paired-associate items for which they were to learn over five or ten training trials, depending on their assigned condition. Twenty-seven paired-associates were used, with three-letter words being used as the stimulus to elicit recall of the corresponding number for each word. Once subjects had completed their allotted number of practice trials, one third of the subjects were given five consecutive test trials (i.e., five tests through the entire paired-associate list), one third a single test trial, and the final third was given no test trials. Twenty-four hours after the completion of experimental trials, all subjects were given a retention test, consisting of four consecutive test trials of the paired-associate list. On the twenty-hour delayed retention test, the group receiving five test trials during acquisition committed significantly fewer errors than the group receiving one test trial, which committed fewer errors than the group receiving no test trials. These data are interpreted to suggest that recall testing during acquisition improved long-term retention. Moreover, the greater number of test trials administered during practice correlated with higher performance on future testing. In support of this finding, Carrier and Pashler (1992) used the same delayed retention interval and observed a reliable advantage in final testing for the study-test condition. The tested group was better able to recall nonsense-syllable/number pairs in comparison to a study-only condition.

Furthermore, Hogan and Kintsch (1971) studied the effects of testing using a longer retention interval of forty-eight hours. The researchers studied this effect by splitting sixty-four college students into one of two conditions: 1) three study trials followed by a test trial (SSST) and 2) one study trial followed by three test trials (STTT). Each subject was given a list of forty words that was selected from a total pool of two hundred and forty words. During study trials, each word was exposed to subjects for two seconds with a half second delay between words. For test trials, subjects were given one hundred seconds to recall as many words as possible from the list they studied. Upon completing all four study/test trials, subjects were administered a forty-eight hour delayed recall test, identical to the ones taken during experimental testing sessions. Data analysis showed the STTT condition was able to recall significantly more items from the word list than their SSST counterparts. The researchers concluded that testing during practice facilitates the retention of information more effectively than only studying words.

While previous studies support testing during periods of practice is advantageous for retaining information over a short delay (twenty-four hours and forty-eight hours), Roediger and Karpicke (2006) looked to examine the effects of testing across both short (five-minute/forty-eight hour) and long-term (one week) retention intervals. To investigate short and long-term retention effects, subjects were randomly assigned into either a study-test or a re-study condition. The experimental phase (phase one) consisted of four seven-minute periods, and for any given period participants may be asked to: i) read a new passage of text, ii) re-study the same text, or iii) be quizzed on the text passage they had just read. Prior to the first period, all subjects were told they would read a new passage of text, while subsequent periods differed by the assignment of a re-study or testing period. Each passage of text contained thirty major idea points, for which subjects were asked to recall during quizzing or retention testing. Upon completion of phase one, all subjects received retention tests at the intervals of five-minutes, forty-eight hours, and one week. At the five-minute interval testing, students who had re-studied the passage recalled more than subjects who had taken recall tests. However, these results were reversed on the forty-eight hour and one-week retention intervals. Subjects who had taken an initial test recalled more than those who had not received a test, with the largest effect between conditions seen at the one-week interval (Roediger & Karpicke, 2006b). It was suggested the testing effect was not simply a result of students gaining re-exposure to the material during tests, as the subjects re-studying the material were actually exposed for a longer period than the study-test subjects (Roediger & Karpicke, 2006b). Despite this fact, the group experiencing tests during study periods outperformed the re-study condition on both of the longer interval tests.

A potential explanation for the results outlined is by virtue of the rate of decay of information in each study condition (i.e., re-study/study-test). Wheeler, Ewers, and Buonanno (2003) showed that when comparing both study methods against one another, the rate of information decay is faster among those who implement the re-study technique. Wheeler and colleagues suggest that testing enhances the retrieval process much in the same way as McDaniel and Masson outlined previously in their explanation of the benefits from encoding variability. The more variable the encoding conditions (i.e., study + test), the greater amount of retrieval routes one is able to develop for a specific bit of information. Wheeler et al. proposed that this increase in number of retrieval routes decreases the rate at which information decays from the brain. For example, it takes longer to forget a bit of information with five retrieval routes versus information with only a single route of retrieval. This is one mechanism used to explain the greater duration of information retention seen in subjects receiving tests versus others simply studying.

Testing Effect in Motor Tasks

The literature investigating the testing effect in motor learning is relatively non-existent and therefore, any possible effects are still relatively unknown. Although the body of literature is very limited, there have been some studies looking at the testing effect using various motor skills. An early experiment in the field by Adams and Dijkstra (1966) studied the effects of testing on short-term memory of a motor skill that required subjects to slide a knob along a bar. Using their right hand, subjects were to move the knob from a given starting point to a target end point marked by a bolt (i.e., moved the knob from point A to point B). The bar was fixed to a table and covered by a sheet to prevent subjects from using visual aid when completing trials. Subjects were assigned to one of three conditions: i) received one reinforcement (test) trial, ii) received three reinforcement trials, and iii) received six reinforcement trials. For each practice trial, the bolt was fixed into place, obstructing the knob from sliding past the desired point. Subjects performed the task repeatedly, getting a feel for when to stop the bar at the target bolt. During the reinforcement (or testing) period the bolt was removed, allowing subjects to potentially slide the bar past the desired point. The objective was to slide the bar, free hand, to the exact location of where the bolt was located prior to being removed. Error measurements were then taken to record the direction and magnitude of errors for each trial. Retention tests were administered at five, ten, fifteen, twenty, fifty, eighty, and one hundred and twenty seconds after the practice period was completed. Collapsing the error totals across all retention interval tests, the condition receiving the most reinforcement trials (six) totalled the least amount of error. That is, the group receiving the most test trials was able to more accurately complete the task. Additionally, Hagman (1983) presented data supporting that of Adams and Dijkstra, showing initial testing decreases the amount of errors made in subsequent testing. This implies that receiving tests stabilizes the short-term memory of a motor movement pattern acquired during practice (Hagman, 1983).

Thus far, the impact of testing on learning a motor skill have been effective over very short retention intervals, however, testing at the culmination of a practice period has also demonstrated effects on the long-term retention of motor movements. One study in particular highlighting the long-term effects of testing used medical students learning a resuscitation skill (Kromann, Jensen & Ringsted, 2009). Students in the practice-test condition were provided with three and a half hours of practice time to acquire the skills being taught while a practice-only group was allotted 4 hours of practice. The test group was then provided half an hour of testing so both groups were exposed to the task for a total of four hours. Upon completion of the experimental phase, a two-week delayed retention test was administered to all subjects. The retention test required subjects to perform the learned resuscitation skills in five different cardiac arrest scenarios. Retention test performance was blindly graded by a set of judges using a twenty-five item checklist. When compared to the practice-only subjects, the practice-test group performed significantly better, achieving an average score of eighty-two percent while their counterparts averaged a mere seventy-three percent.

An additional study produced similar results, displaying enhanced long-term retention of both distance and location using similar sliding knob task used by Adams and Dijkstra (Hagman, 1983). In this study, Hagman observed a negative effect when administering testing during the practice trials. It was noted that testing during the acquisition period produced error increases in accuracy. That is, subject's initial performance level worsened as a result of testing. Conversely, the practice-only condition performed better during the acquisition phase, with slight improvements seen throughout practice. Although the practice-only condition experienced increased practice performance, they suffered from greater decrement in short-term and long-term performance. It was suggested that this negative effect on practice performance is the result of increased difficulty associated with testing, making it more difficult to encode the motor movements associated with a skill. It is precisely this difficulty that leads to poor practice performance, however, allows for stronger encoding of a motor movement and ultimately results in a more stable motor movement that is retained over a greater period of time (Hagman, 1983).

Multiple learning frameworks have been proposed over the years in both cognitive and motor learning domains outlining the benefits of difficulty during the learning process. Some of the beneficial outcomes of this difficulty is a greater understanding of information alongside longer retention of the information. One framework, known a *Desirable Difficulties*, suggests that learning occurs most efficiently when certain difficulties are introduced to the learning process (Bjork, 1994). These difficulties, one of which is testing, require the learner to engage in more elaborate encoding and retrieval processes. Deeper elaboration of encoding and retrieval processes require time to solidify in the brain. While the solidification process is occurring, recall ability is poor, resulting in initial performance decreases followed by performance increases upon solidification (Kleinsmith & Kaplan, 1963). Furthermore, the *Challenge Point Framework* suggests learning is related to the information arising from a performance. One is able to learn new information based on their previous performance (Guadagnoli & Lee, 2004). When combining these learning frameworks, one can hypothesize that testing creates a difficulty in the learning environment or process, and as a result, new information is provided to the learner. Conversely, a pure study or practice condition is not presented with this difficulty during the learning process and therefore not provided the opportunity to learn from the information provided by it.

Arousal Related to Learning

In an attempt to understand the mechanism behind the effects of testing, many different avenues have been taken, including observing the role of arousal. Some studies suggest that an optimal level of arousal (which testing may produce) is appropriate for efficient learning (Eysenck, 1976; Kleinsmith & Kaplan, 1963). As a measure of arousal, previous studies have used basal resistance level of the skin (Walker & Tarte, 1963; Kleinsmith & Kaplan, 1963), salivary cortisol (Cahill, Gorski & Le, 2003), and an electro dermal skin response (Cahill & Alkire, 2003). Although these studies are different in the biomarkers assessed, each sought to measure the arousal level of subjects at a given point in time. As a preview, one study showed that items learned under high arousal had low immediate recall and high delayed recall while the opposite was true for those items learned under low arousal (Walker & Tarte, 1963; Cahill, Gorski & Le, 2003). The effects of learning under high arousal correspond to the outcomes observed with testing, where high arousal groups (test conditions) experience poor immediate recall followed by superior delayed recall.

A more in depth explanation of arousal's impact on learning comes from Kleinsmith and Kaplan, where the authors discuss what Pare (1963) called "reverberating neural circuits," to explain the effect of arousal levels on consolidation (Kleinsmith & Kaplan, 1963; Pare, 1963). The reverberating neural circuits theory states that consolidation is a result of neurons firing rapidly and repeatedly in an organized manner. Pare, using medication to stimulate or depress arousal, was able to manipulate the learning potential of a subject. What Pare found was a correlation between information learned under high arousal levels and longer retention of the learned information. In conditions of low arousal, reverberation is low as neuron firing is very limited, however, when arousal is high, neuron activity is heightened and reverberation is increased or maximized (a series of neurons firing represents a bit of information). While reverberation is taking place, the learner experiences difficulty accessing the memory trace, leading to poor initial recall. The difficulty in accessing the memory trace arises from the attempt to re-stimulate (or fire) a neuron that is already being fired as part of the reverberation process (Kleinsmith & Kaplan, 1963). As a result, short-term performance suffers during practice testing due to the consolidation process-taking place. Additionally, Hodgkin (1948) suggested that neurons are limited in their maximal rate of firing, which under high arousal, helps to explain the decrease in immediate performance during testing conditions. As stated previously, conditions of high arousal stimulate high amounts of neural activity, especially during the reverberation process. When neurons are firing at their maximal rate, the neuron is unable to fire any faster for memory retrieval, and thus the memory is difficult to retrieve until reverberation terminates (Hodgkin, 1948).

CHAPTER 3

METHODOLOGY

Introduction

The primary focus of this study was to investigate the relationship between the testing effect and the corresponding arousal levels for motor skill learning. Specifically, the purpose of the study was to uncover the mechanism behind how the testing effect impacts the learning process. It is predicted that testing produces an increased level of arousal that is more appropriate for efficient learning. The specific to-be-learned motor skill for the study is golf putting. Moreover, putting is a skill used by many and has great practical application in real world scenarios. There are two research question being tested in the current study:

1. Does the testing effect impact the learning efficiency of a motor skill?
2. Does the perception of being tested affect arousal during acquisition and what are the effects of arousal level on learning a motor skill?

A mixed model design was used to compare practice and practice-test conditions. Subjects in either condition completed an identical task, however, their perception of the task was manipulated depending on their assigned condition. For practice trials subjects were told: "These next 15 putts are practice putts. Please do your best," while for test trials subjects were instructed: "These next 15 putts are test putts. Please do your best." This perception of testing is thought to raise arousal level to a level more conducive for efficient learning (Walker & Tarte, 1963; Cahill, Gorski & Le, 2003). We hypothesized that the practice-test condition will have a higher arousal level during the testing blocks of the experimental phase, something similar to that which will be experienced during final testing. However, the practice condition will have a lower arousal level during the experimental blocks and a spike in arousal on during final testing. This spike in final testing arousal is thought to lead to performance decreases in final testing relative to the practice-test condition. Additionally, we expect the practice condition will experience incremental gains throughout the experimental phase of the study whereas the practice-test condition's performance will be hindered slightly during the experimental phase (Hagman, 1983).

As a measure of arousal, the present study utilized a salivary α-amylase (sAA) spit test. Salivary α-amylase is an enzyme that accounts for 40-50% of the overall protein secreted from the salivary glands (Nater & Rohleder, 2009). While the primary function is to initiate digestion of food in the mouth, sAA is released from the salivary glands in response to β-adrenergic stimuli – or epinephrine (Gallacher & Peterson, 1983). Because of this, sAA has been utilized as a marker that is highly sensitive to physiological (Chatterton, Vogelsong, Lu & Peterson, 1996; Nexo, Hansen & Konradsen, 1988) and psychological (Bosch, Turkenburg, Nazmi, Veerman, de Geus & Amerongen, 2003; Skosnik, Chatterton, Swisher & Park, 2000; Noto, Sato, Kudo, Kurata, & Hirota, 2005) stress-related changes. Bosch and colleagues reported that acute stress causes specific changes to saliva composition, such as the level of salivary α-amylase present. For these reasons, sAA was utilized as an arousal indicator in the current investigation.

Participants

A total of 24 subjects between the ages of 18-30 were recruited from the University of Nevada, Las Vegas (UNLV) campus to participate in the study. All participants were free of any neurological deficits and were classified as low-skilled golfers. Specifically, the criterion for inclusion was that players could not have played more than 5 rounds of golf in the past year and they must possess a handicap of 14 or higher. Subjects who were not familiar with what a handicap was were classified as beginners and included in the study.

Participants were instructed to brush their teeth at a timeframe greater than 45 minutes and to have had no dental work done 24-hours prior to sampling. Participants were also asked not to have a major meal within 60-minutes of sampling, and to avoid foods with high sugar, acidity, or caffeine immediately prior to entering the lab. These guidelines were established to avoid unreliable saliva sampling.

Experimental Design

The primary experimental design of the study was a 2 (condition) x 2 (test) mixed design. The between-subject factor (condition) had 2 levels: i) Practice condition and ii) Practice-test condition. The within-subjects factor was test (pre- and post-test). All subjects completed a pre-test, five blocks composed of 15 practice/test trials, and a post-test. The dependent measures of interest were arousal level (salivary α-amylase), putting stroke kinematics (acceleration and face-to-path), and end-point error (absolute error and variance).

Experimental Procedures

Upon arriving to the data collection room, participants were provided with the informed consent form which they read and signed. Participants then provided their height, weight, and date of birth for researcher records. Participants were also given a water bottle for which they were to rinse out their mouth. A 10-minute break was given as the initial part of the study protocol, during which time they were to become comfortable with their surroundings. Once the break was complete, the first unstimulated saliva sample was collected utilizing the passive drool technique. The passive drool technique is as follows: participants were given a sterile cryovial (tube) and a 2-inch plastic mouth fitting attached to the cryovial (Salimetrics LLC, State College, PA). Participants placed their lips over the mouth fitting, tilted their head down, and allowed the saliva to run down the plastic tube and into the cryovial. Approximately one millilitre of saliva was needed per sample for analysis. Saliva samples were placed on ice at 4° C until all samples were obtained (no longer than 2-hours), and then frozen at -55°C until analysis was done using commercially available α-amylase kits purchased from Salimetrics. This initial saliva sample was used as a representation of each participant's base-line level of arousal.

After the initial saliva sample was taken, a set of verbal instructions was read to each participant that was standard across all participants. Following the instructions was a short video of an expert putter as an example of the task to be completed as well as a potential putting technique. The video was provided simply as a demonstration and participants were not required to replicate the expert's technique.

The putting task performed required participants to stand at one end of a custom built putting platform that was 16 feet long, 4 feet wide, and covered with a carpet similar to a 10-stimp meter putting green speed. Participants stood at one end of the platform approximately 10 feet (3 meters) away from the target, which was located at the other end of the platform. The target "hole" was represented by a 8.25-cm diameter circle (the same size as a regulation golf hole) drawn onto the carpet. The same standard blade putter was used across all participants and were asked to putt each golf ball as accurately as they could relative to the target hole.

Prior to the pre-test, subjects were given three putts as a warm up to gather information on how to adequately complete the task (i.e., direction and force to hit the golf ball with). No data was recorded for these putts; they were administered simply to avoid participants putting the ball off of the putting platform during pre-testing. To begin the pre-test, participants were given the following instructions: “These next 5 putts are a *baseline measurement* of your putting abilities. Please do your best.”, followed by providing the second saliva sample. The participant then completed the five pre-test putts which were all identical (as well as experimental and post-test putts), beginning 10-feet from the starting point to the target hole. After each of the putting blocks (baseline measure and experimental trials) participants were given a 2-minute break for which they sat in a chair located beside the putting platform.

After the pre-test, all participants completed five blocks of 15 putts for a total of 75 experimental putts. The practice condition was given five consecutive practice blocks, separated each by a 2-minute break. Participants in the practice-test condition also completed five blocks of 15 putts for a total of 75 putts. However, for this condition, blocks two and four were considered test blocks. As mentioned prior, the putts were identical, however, the instructions differed in that practice blocks were given the instructions: “These next 15 putts are *practice* putts. Please do your best.”, and test blocks were told: “These next 15 putts are *test* putts. Please do your best.”

Prior to each of the baseline measure, five experimental blocks, and the final test, participants provided a saliva sample using the method described earlier. A total of 8 saliva samples were collected to analyze.

Upon completing the final block of experimental trials, participants were given a rest period of 10-minutes. During the rest period, participants were required to sit quietly in a chair and relax. Once the 10-minute break expired, participants were read the post-test instructions: “These next five putts are the *final test*. Please do your best.”, provided the final saliva sample, and completed the five post-test putts.

Data was collected using three different sources: 1) Salivary amylase samples were collected as a measure of arousal prior to the pre-test, experimental trials, and post-test, 2) a computerized SAM Puttlab system measured putter kinematics such as acceleration of the putter head as it strikes the golf ball and putter face-to-path relationship, and 3) an end point measure of accuracy relative to the target measured via a grid system. The grid was composed of 2.54 x 2.54 cm squares drawn onto the putting platform using a black marker. The researcher observed where the ball came to rest and recorded the X and Y coordinates into an excel spreadsheet. The spreadsheet was then set up to calculate the direct distance measure from ball to target using Pythagorean’s Theorem to calculate the hypotenuse (Z-direction score).

Salivary Amylase Methods

On the day of analysis, samples were thawed, vortexed, and centrifuged at 1500 x g for 15-minutes. The sAA calorimetric ELISA assay was performed as described by the manufacturer (Salimetrics LLC, State College, PA). Briefly, 10 milliliters (mL) of saliva was diluted with 90 mL of diluent, and 10 mL of this mixture was further diluted with 190 mL of diluent. 8 mL of controls (high and low) and samples were added to appropriate wells on the microtiter plate. 320 mL of preheated 37° C α-amylase substrate solution was then added to each well and optical density was read at 1-minute and 3-minutes on a microplate spectrophotometer (Epoch, BioTech Instruments Inc., Winooski, VT) at 405 nm. Salivary a-amylase concentration ($U \cdot mL^{-1}$) was determined according to the following equation: change in absorbance between minute 3 and minute 1 x 0.328 x 200/12.9 x 0.008 x 0.97, where 0.328 represents the total volume of the assay, 200 represents the dilution factor, 12.9 represents the milli molar absorptivity of 2-chloro-p-nitrophenol, 0.008 represents the sample volume, and 0.97 represents the light path specific to the microtiter plate.

CHAPTER 4

RESULTS

Acquisition data and retention data were analyzed separately. With all performance related dependent measures two error measures were used. Absolute error (AE) was used as a measure of accuracy relative to the target, and variance (VAR) was used as a measure of consistency of performance. The Huynh-Feldt correction factor was used in the analysis when appropriate.

End Point Error

Absolute Error

End point error is the magnitude of difference between the target value and the final resting position of each putting trial. End point error was measured in three different directions: x, y, and z. The x-measure reflected the error in the lateral direction (that is, left and right of the target). The y-measure reflected the error in the distance direction (that is, too long or too short relative to the target). The z-measure reflected the composite error in the lateral plus distance directions (that is, the hypotenuse of the x and y errors). For all practice block analyses, z-measure data was used, while pre- post-test data were stratified using the x-measure, y-measure, and z-measures.

Absolute error acquisition data were analyzed using a 2 [*Group* (Pre-test and Post-test)] x 5 [*Block* (Practice blocks 1-5)] analysis of variance (ANOVA), with repeated measures on the last factor. The analysis demonstrated no main effects for *Group* $\underline{F}$ (1, 22) = 1.458, $\underline{p} > .05$, or *Block* $\underline{F}$ (4, 88) = .071, $\underline{p} > .05$, suggesting both participant groups did not improve their performance as they practiced putting. Most importantly, no significant *Group* x *Block* interaction was found $\underline{F}$ (4, 88) = 2.242, $\underline{p} > .05$.

X-measure. Absolute error data along the x-axis were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. From the analysis, no main effects were found for *Group* $F(1, 22) = 2.651$, $p > .05$, or *Test* $F(1, 22) = 2.124$, $p > .05$, indicating no change in performance in the x-measure within or between groups from pre- to post-testing. Lastly, no significant *Group* x *Test* interaction $F(1, 22) = 1.529$, $p > .05$ was found.

Y- measure. Absolute error data along the y-axis were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. Results from the analysis revealed no main effects for *Group* $F(1, 22) = 1.118$, $p > .05$, or *Test* $F(1, 22) = 1.340$, $p > .05$. Finally, the *Group* x *Test* interaction $F(1, 22) = .092$, $p > .05$ was insignificant.

Z-measure. Absolute error data in the composite direction were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. The analysis revealed no main effects for *Group*, $F(1, 22) = 1.729$, $p > .05$, *Test* $F(1, 22) = 1.568$, $p > .05$, or the *Group* x *Test* interaction $F(1, 22) = .014$, $p > .05$. The lack of interaction indicates that, in terms of end point error, participants in both groups did not significantly improve their putting through practice.

Variance

Variance in acquisition data were analyzed using a 2 [*Group* (Pre-test and Post-test)] x 5 [*Block* (Practice blocks 1-5)] analysis of variance (ANOVA), with repeated measures on the last factor. The analysis revealed no significant main effects for *Group* $F(1, 22) = .264$, $p > .05$, or *Block* $F(4, 88) = 2.098$, $p > .05$. Lastly, the analysis uncovered a trend towards significance in the

Group x *Block* $\underline{F}$ (4, 88) = 2.469, $\underline{p}$ = .057 interaction, suggesting variance was declining as participants practiced across the five blocks.

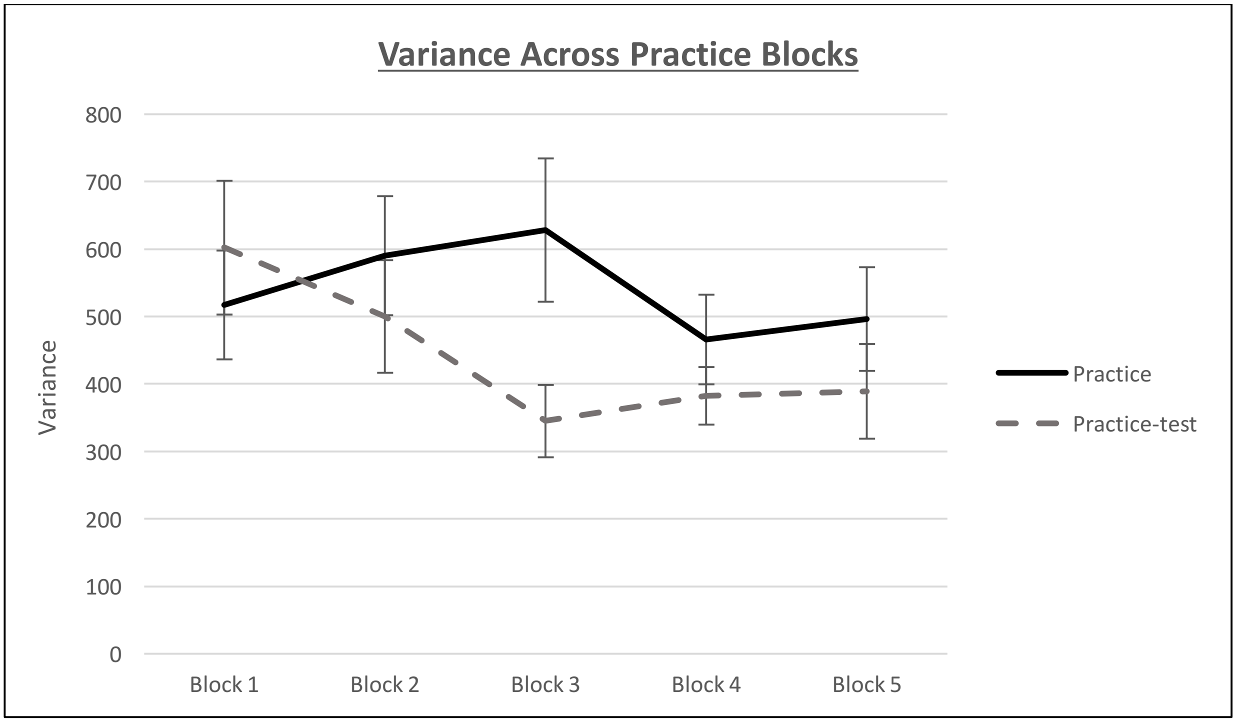

Figure 1: Displays the variance in z-measure direction for each group across practice blocks.

X-measure. Pre- post-test data along the x-axis were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. The analysis revealed no significant main effects for *Group* $\underline{F}$ (1, 19) = 1.265, $\underline{p} > .05$, or *Test* $\underline{F}$ (1, 19) = 1.159, $\underline{p} > .05$. Additionally, no significant *Group* x *Test* $\underline{F}$ (1, 19) = .181, $\underline{p} > .05$ interaction was found from the analysis.

Y-measure. Pre- post-test data along the y-axis were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. The analysis revealed no significant main effect for *Group* $\underline{F}$ (1, 22) = 2.097, $\underline{p} > .05$. A significant main effect was found for *Test* F (1, 22) = 8.452, p < .05. Additionally, there was no significant *Group* x *Test* interaction F (1, 22) = .348, p > .05.

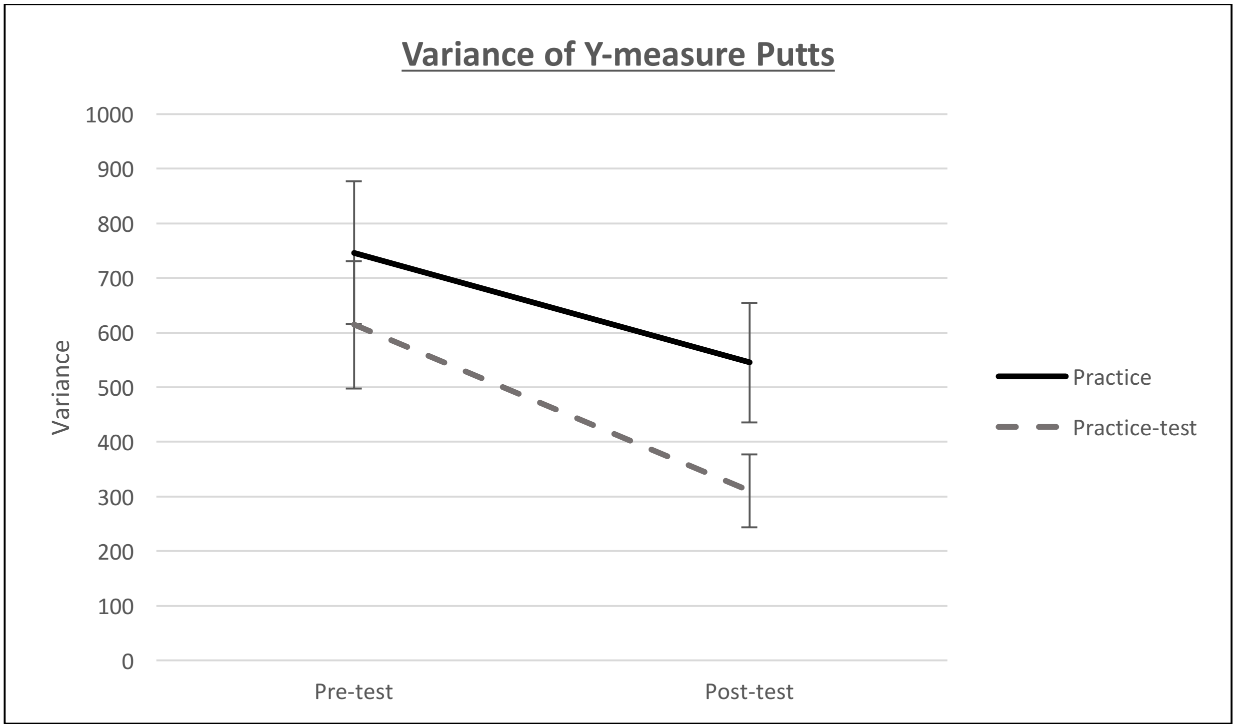

Figure 2: Illustrates the variance of putting distance (i.e., short or long of the target) of each group across pre- and post-tests.

Z-measure. Pre- post-test data for end point error in the composite z-direction were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. Results from the analysis revealed no main effect for *Group* F (1, 22) = 2.260, p > .05. Additionally, a significant main effect for *Test* F (1, 22) = 9.033, p < .05 was found. There was no significant *Group* x *Test* F (1, 22) = .286, p > .05 interaction.

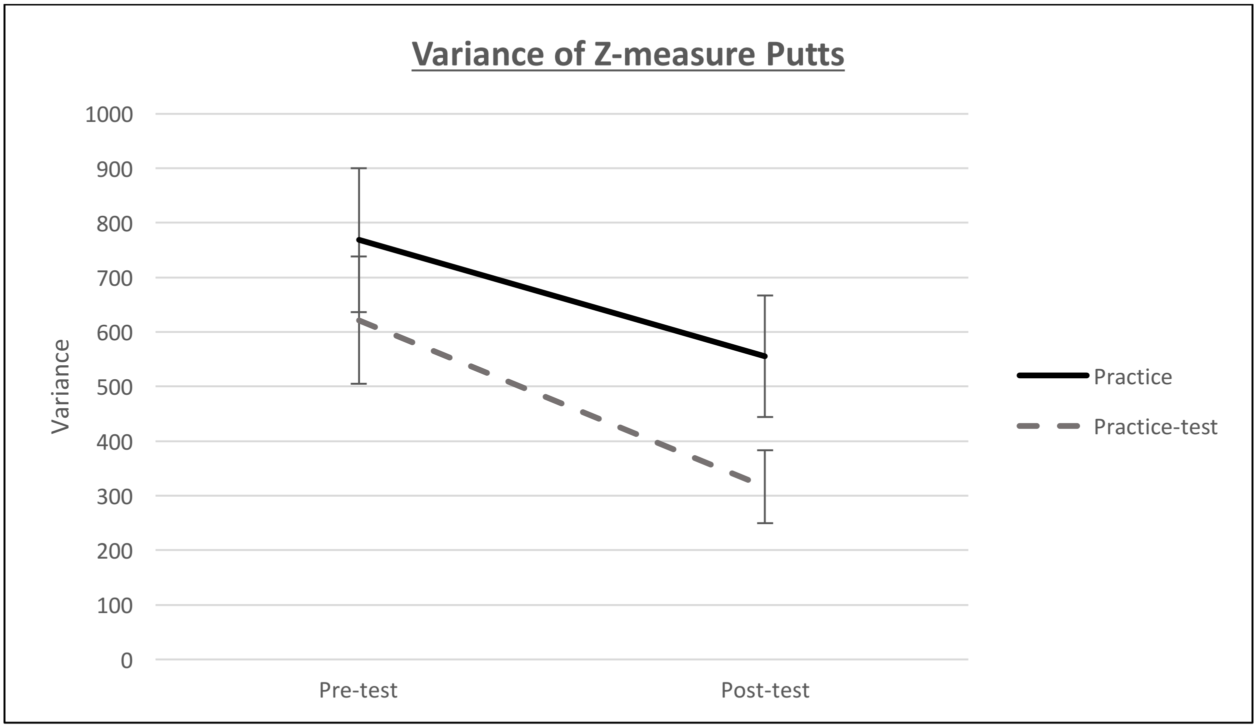

Figure 3: Shows the variance in composite (x and y directions) end point error for both groups across pre- and post-tests.

Putting Stroke Kinematics

Absolute Error

Data were collected on two aspects of each putting stroke to characterize any changes occurring in the kinematics of putting. The first variable was acceleration, which reflected the acceleration profile of the putter head at contact with the golf ball (i.e., acceleration or deceleration). An acceleration rate of zero at ball contact was considered optimal. The second putting characteristic for which data was collected on was the face-to-path variable. This variable reflects the relationship between the putter face and putting stroke direction (i.e., club is open, square, or closed relative to the swing path of the putter head). A square club face relative to swing path is ideal for putting.

Acceleration. Absolute error putting stroke data for acceleration were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. The analysis indicated no main effects for *Group* $\underline{F}$ (1, 22) = 1.114, $\underline{p} > .05$, or *Test* $\underline{F}$ (1, 22) = .409, $\underline{p} > .05$. More importantly, the analysis revealed no *Group* x *Test* $\underline{F}$ (1, 22) = 2.761, $\underline{p} > .05$ interaction effect, indicating that both groups practicing over five blocks of trials had similar effect on the acceleration profiles of participants.

Face-to-path. Absolute error for the face-to-path data were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. Results from the analysis showed a significant main effect for *Group* $\underline{F}$ (1, 22) = 6.941, $\underline{p} < .05$. No significant main effect was found for *Test* $\underline{F}$ (1, 22) = 3.467, $\underline{p} > .05$. A trend towards significance was seen in the *Group* x *Test* $\underline{F}$ (1, 22) = 3.449, $\underline{p} = .077$ interaction.

Variance

Acceleration. Variability in the acceleration profile of the putting stroke were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. The analysis revealed no significant main effects for *Group* $\underline{F}$ (1, 22) = 1.115, $\underline{p} > .05$, or *Test* $\underline{F}$ (1, 22) = 2.001, $\underline{p} > .05$. No significant *Group* x *Test* interaction $\underline{F}$ (1, 22) = 2.820, $\underline{p} = .107$ resulted from the analysis, indicating a similar decrease in variability for the putting stroke characteristic of acceleration between groups.

Face-to-path. Variability in the face-to-path relationship were analyzed using a 2 [*Group* (Practice and Practice-test)] x 2 [*Test* (Pre-test and Post-test)] ANOVA, with repeated measures on the last factor. The analysis revealed no significant main effects for *Group* $\underline{F}$ (1, 22) = .544, $\underline{p}$

> .05, or *Test* F (1, 22) = 1.106, p > .05. Lastly, the analysis maintained there was no significant *Group* x *Test* interaction F (1, 22) = .515, p > .05, suggesting an equal improvement in variability for the face-to-path variable between groups.

Biological Measures

Salivary α-amylase was collected as the biological measure of arousal level. Eight different samples were collected at various points of the study, with the first sample representing the participants baseline level of arousal. Percent change from the baseline was calculated for each of samples two through eight and used for the purposes of the analysis.

Salivary α-amylase data were analyzed using a 2 [*Group* (Practice and Practice-test)] x 8 [*Time* (Samples 1-8)] ANOVA, with repeated measures on the last factor. The analysis revealed no significant main effects for *Group* F (1, 21) = .026, p > .05, or *Time* F (7, 147) = .542, p > .05. Additionally, there was no significant *Group* x *Test* interaction F (7, 147) = .515, p > .05, indicating no significant differences in arousal between groups across time.

CHAPTER 5

DISCUSSION

The present study was designed to investigate what impact the testing effect has on learning a motor skill, more specifically, the skill of putting. Furthermore, the study intended to uncover whether the perception of being tested affects arousal level, and whether these changes in arousal level are associated with changes in motor learning efficiency. The perception of being tested (i.e., practice or test putts) during the acquisition phase of the study was the manipulation used between groups. The practice group was not given any test putts during acquisition while the practice-test group was given test putts on two out of the five acquisition blocks. The dependent errors of interest were in three categories: variance of performance, a measure of arousal level, and accuracy of performance during practice. Each of these will be discussed below. Although the testing effect did not significantly affect the x, y, or z-measures of absolute end point error, an improvement was seen in the variability of putting trials. That is to say, on average, participants did not putt the ball closer to the hole from pre-test to post-test, but they significantly increased the consistency of putts in both the y-measure (long and short of the target) and z-measures (composite of x and y-measures).

Variance of performance quantifies how close together or spread out a set number of trials are from the mean of those trials. The key finding here can be identified as the increase in consistency seen in putting during final testing as a result of the prior periods of practice. Through practice, novice golfers were able to reduce the variance from trial to trial in the putting task. For example, the practice group showed roughly a twenty-five percent decrease in variance while the practice-test group was able to reduce their variance by almost fifty percent from pre- to post-test.

The finding here leads us to suggest that accuracy may not be the most important aspect to putting, but rather, increases in skill level may have more to do with increasing one's consistency from putt to putt. For example, if a golfer is missing putts both left and right of the hole from trial to trial, it is very difficult to make corrections necessary to account for misses in multiple directions. On the other hand, a golfer who consistently misses putts to the right of the hole is more easily able to make the correction necessary to increase their putting accuracy (i.e., aim more left). In this regard, it may be that limiting variability is the key variable of putting that leads to improvements in skill.

Furthermore, it was expected that a heightened level of arousal would be associated with the perception of being tested. Increases in arousal level were expected to occur at each of the practice testing points of the study (i.e., acquisition block tests) in addition to pre- and post-testing. While small spikes in arousal level were observed for both the pre- and post-test, there was no significant increase in arousal level during acquisition phase testing. It was thought that simply telling participants they were being tested would lead to a biological response similar to that of a real testing experience. This lack of an increase in arousal suggests that a real testing environment and the perception of being tested are, biologically, two different events. It may be that the perception of being tested and actually being tested produce two different results in terms of learning and performance.

Accuracy for this study was referred to as the absolute distance each putt came to rest from the target. A second anticipated finding was that increases in performance accuracy would be apparent as a result of practice. For example, it was predicted that a participant undergoing a certain amount of practice trials (in this case seventy-five trials over five blocks) would be able to putt the ball with increased accuracy towards a target. That is, there was a predicted pre-test to post-test effect for putting accuracy. This effect was not seen in the results, as participants in both groups failed to significantly improve their putting accuracy across pre- and post-testing. A possible explanation for this finding, or lack there-of, is the difficulty associated with the putting task relative to novice skill level golfers. It may be that the complexity of learning a motor task such as putting may have required learners to focus solely on learning the movements associated with putting rather than focusing on the accuracy of each putt. In other words, the coordination of movements associated with the putting task may have required the participant's full attention, leaving them unable to focus on the end target of the putt. This is also reflected in the reduced variability across practice trials, suggesting participants were better able to move their body in a more consistent manner as a result of practice.

Future Recommendations

One of the limitations of this study may be the population from which individuals were sampled. Specifically, the subject pool was made up of novice golfers with very low skill level. The lack of skill might have been the root cause of the variability seen in the data. The variability was very high both within (i.e., 5 post-test putts) and between subject (i.e., variability of a group at post-test) performances, potentially clouding any of the possible outcomes of the testing effect. That is, if there is some effect to be seen, it is being hidden by the high variability produced from the novice golfers. To see if there is any effect from using testing to improve performance of a motor skill, the current study could be altered in an attempt to reduce variability. The first change in which variability could be reduced is to use the same participants while extending the number of practice blocks. This may allow participants a greater amount of practice trials to improve their putting and reduce the variability from trial to trial. A second manner in which variability could be reduced is by the use of more skilled participants, such as those who have played golf for a longer period of time and are more familiar and proficient i.e., lower handicap golfers) with the motor skill of putting. It is predicted that more experienced players would be more consistent (or less variable) from putt to putt.

Conclusion

In conclusion, using testing during practice appears to have the same effect on learning as simply practicing. End point accuracy did not improve for either group, suggesting that testing has no effect on the accuracy of putting. However, variability was significantly reduced following practice, but the rate of improvement was similar between both practice and practice-test groups. Although no significant group differences resulted from the use of testing, the large amount of variability observed in both groups appeared to have concealed any possible effects of testing. The use of novice golfers and the complexity of the putting task led to the high variability observed in the study. Although it seems as though an effect is possible from using the testing effect to learn a motor skill, these results suggest there are no additional affordances to motor learning efficiency that the testing effect provides to novice golfers that one cannot achieve using traditional practice methods.

REFERENCES

1. Adams, J. A., & Dijkstra, S. (1966). Short-term memory for motor responses. *Journal of Experimental Psychology*, *71*(2), 314.

2. Allen, G. A., Mahler, W. A., & Estes, W. K. (1969). Effects of recall tests on long-term retention of paired associates. *Journal of Verbal Learning and Verbal Behavior*, *8*(4), 463-470.

3. Bartlett, J. C. (1977). Effects of immediate testing on delayed retrieval: Search and recovery operations with four types of cue. *Journal of Experimental Psychology: Human Learning and Memory*, *3*(6), 719.

4. Berlyne, D. E., Borsa, D. M., Hamacher, J. H., & Koenig, I. D. (1966). Paired-associate learning and the timing of arousal. *Journal of Experimental Psychology*, *72*(1), 1.

5. Bosch, J. A., Turkenburg, M., Nazmi, K., Veerman, E. C., de Geus, E. J., & Amerongen, A. V. N. (2003). Stress as a Determinant of Saliva-Mediated Adherence and Coadherence of Oral and Nonoral Microorganisms. *Psychosomatic medicine*, *65*(4), 604-612.

6. Boutin, A., Badets, A., Salesse, R. N., Fries, U., Panzer, S., & Blandin, Y. (2012). Practice makes transfer of motor skills imperfect. *Psychological research*, *76*(5), 611-625.

7. Boutin, A., Panzer, S., & Blandin, Y. (2013). Retrieval practice in motor learning. *Human movement science*, *32*(6), 1201-1213.

8. Boutin, A., Panzer, S., Salesse, R. N., & Blandin, Y. (2012). Testing promotes effector transfer. *Acta psychologica*, *141*(3), 400-407.

9. Cahill, L., & Alkire, M. T. (2003). Epinephrine enhancement of human memory consolidation: interaction with arousal at encoding. *Neurobiology of learning and memory*, *79*(2), 194-198.

10. Cahill, L., Gorski, L., & Le, K. (2003). Enhanced human memory consolidation with post-learning stress: interaction with the degree of arousal at encoding. *Learning & Memory*, *10*(4), 270-274.

11. Carrier, M., & Pashler, H. (1992). The influence of retrieval on retention. *Memory & Cognition*, *20*(6), 633-642.

12. Chatterton, R. T., Vogelsong, K. M., Lu, Y. C., Ellman, A. B., & Hudgens, G. A. (1996). Salivary α-amylase as a measure of endogenous adrenergic activity. *Clinical physiology*, *16*(4), 433-448.

13. Cull, W. L. (2000). Untangling the benefits of multiple study opportunities and repeated testing for cued recall. *Applied Cognitive Psychology*, *14*(3), 215-235.

14. Darley, C. F., & Murdock, B. B. (1971). Effects of prior free recall testing on final recall and recognition. *Journal of Experimental Psychology*, *91*(1), 66.

15. Guadagnoli, M. A., & Lee, T. D. (2004). Challenge point: a framework for conceptualizing the effects of various practice conditions in motor learning. *Journal of motor behavior*, *36*(2), 212-224.

16. Hagman, J. D. (1983). Presentation-and test-trial effects on acquisition and retention of distance and location. *Journal of experimental psychology: Learning, memory, and cognition*, *9*(2), 334.

17. Hanawalt, N. G., & Tarr, A. G. (1961). The effect of recall upon recognition. *Journal of Experimental Psychology*, *62*(4), 361.

18. Hodgkin, A. L. (1948). The local electric changes associated with repetitive action in a non-medullated axon. *The Journal of physiology*, *107*(2), 165.

19. Hogan, R. M., & Kintsch, W. (1971). Differential effects of study and test trials on long-term recognition and recall. *Journal of Verbal Learning and Verbal Behavior*, *10*(5), 562-567.

20. Kleinsmith, L. J., & Kaplan, S. (1963). Paired-associate learning as a function of arousal and interpolated interval. *Journal of experimental psychology*, *65*(2), 190.

21. Kromann, C. B., Jensen, M. L., & Ringsted, C. (2009). The effect of testing on skills learning. *Medical education*, *43*(1), 21-27.

22. Maruyama, Y., Gallacher, D. V., & Petersen, O. H. (1983). Voltage and Ca2+-activated K+; channel in baso-lateral acinar cell membranes of mammalian salivary glands. *Nature, 302*(5911), 827-829.

23. McDaniel, M. A., & Fisher, R. P. (1991). Tests and test feedback as learning sources. *Contemporary Educational Psychology*, *16*(2), 192-201.

24. McDaniel, M. A., & Masson, M. E. (1985). Altering memory representations through retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *11*(2), 371.

25. McDaniel, M. A., Anderson, J. L., Derbish, M. H., & Morrisette, N. (2007). Testing the testing effect in the classroom. *European Journal of Cognitive Psychology*, *19*(4-5), 494-513.

26. McDaniel, M. A., Roediger, H. L., & McDermott, K. B. (2007). Generalizing test-enhanced learning from the laboratory to the classroom. *Psychonomic bulletin & review*, *14*(2), 200-206.

27. Nater, U. M., & Rohleder, N. (2009). Salivary alpha-amylase as a non-invasive biomarker for the sympathetic nervous system: current state of research. *Psychoneuroendocrinology*, *34*(4), 486-496.

28. Nexø, E., Hansen, M. R., & Konradsen, L. (1988). Human salivary epidermal growth factor, haptocorrin and amylase before and after prolonged exercise. *Scandinavian journal of clinical and laboratory investigation*, *48*(3), 269-273.

29. Noto, Y., Sato, T., Kudo, M., Kurata, K., & Hirota, K. (2005). The relationship between salivary biomarkers and state-trait anxiety inventory score under mental arithmetic stress: a pilot study. *Anesthesia & Analgesia*, *101*(6), 1873-1876.

30. Pashler, H., Rohrer, D., Cepeda, N. J., & Carpenter, S. K. (2007). Enhancing learning and retarding forgetting: Choices and consequences. *Psychonomic bulletin & review*, *14*(2), 187-193.

31. Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in cognitive sciences*, *15*(1), 20-27.

32. Roediger, H. L., & Karpicke, J. D. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science*, *1*(3), 181-210.

33. Roediger, H. L., & Karpicke, J. D. (2006b). Test-enhanced learning taking memory tests improves long-term retention. *Psychological science*, *17*(3), 249-255.

34. Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological science*, *3*(4), 207-217.

35. Skosnik, P. D., Chatterton, R. T., Swisher, T., & Park, S. (2000). Modulation of attentional inhibition by norepinephrine and cortisol after psychological stress. *International Journal of Psychophysiology*, *36*(1), 59-68.

36. Szpunar, K. K., Khan, N. Y., & Schacter, D. L. (2013). Interpolated memory tests reduce mind wandering and improve learning of online lectures. *Proceedings of the National Academy of Sciences*, *110*(16), 6313-6317.

37. Van Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based instructional strategies. *American Journal of Physics*, *59*(10), 891-897.

38. Walker, E. L., & Tarte, R. D. (1963). Memory storage as a function of arousal and time with homogeneous and heterogeneous lists. *Journal of Verbal Learning and Verbal Behavior*, *2*(1), 113-119.

39. Wheeler, M., Ewers, M., & Buonanno, J. (2003). Different rates of forgetting following study versus test trials. *Memory*, *11*(6), 571-580.

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Pauls, A. L., Guadagnoli, M.A., Bertram, C.P. The savior or The Downfall of Modern Golf Instruction? (Publisher editing).

Bertram, C.P., Guadagnoli, M.A., Pauls, A. L., From Novice Golfer to Expert – From Conscious Control to Automatic Control (Writing Results).

Lima de Albuquerque, L., Poston, B., Pauls, A. L. The Influence of Transcranial Random Noise Stimulation on Motor Skill Acquisition and Learning in a Modified Golf Putting Task (Publisher editing)

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Guadagnoli, M. A., Navalta, J. Pauls, A. L. (2016). The Impact of Intermittent Quizzes on Learning.

Manuscript Reviews

Expecting to Teach Enhances Learning: Evidence from a Motor Learning Paradigm. *Journal of Motor Learning and Development.* (2015).

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Lima de Albuquerque, L., Poston, B., Pauls, A. L. The Influence of Transcranial Random Noise Stimulation on Motor Skill Acquisition and Learning in a Modified Golf Putting Task.