THE EFFECT OF ATTENTIONAL FOCUS INSTRUCTIONS ON GOLF SWING PERFORMANCE IN RECREATIONAL GOLFERS

by

Jeffrey D. Eggleston

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Exercise and Sport Studies

Boise State University

August 2014

BOISE STATE UNIVERSITY GRADUATE COLLEGE

DEFENSE COMMITTEE AND FINAL READING APPROVALS

of the thesis submitted by

Jeffrey D. Eggleston

Thesis Title: The Effect of Attentional Focus Instructions on Golf Swing Performance in Recreational Golfers

Date of Final Oral Examination: 08 May 2014

The following individuals read and discussed the thesis submitted by student Jeffrey D. Eggleston, and they evaluated his presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

Eric L. Dugan, Ph.D.	Co-Chair, Supervisory Committee
Laura J. Petranek, Ph.D.	Co-Chair, Supervisory Committee
Yong Gao, Ph.D.	Member, Supervisory Committee

The final reading approval of the thesis was granted by Eric L. Dugan, Ph.D., Co-Chair of the Supervisory Committee, and Laura J. Petranek, Ph.D., Co-Chair of the Supervisory Committee. The thesis was approved for the Graduate College by John R. Pelton, Ph.D., Dean of the Graduate College.

ACKNOWLEDGEMENTS

I would like to thank my advisors Dr. Eric Dugan and Dr. Laura Petranek for aiding me in finishing this thesis. Without their help, none of this would have been possible.

Secondly, I also want to think my family for supporting me throughout this entire process. Even though this thesis took me away from them, they continued supporting me knowing the good that would come from this.

Lastly, I would like to thank all of the interns and staff at COBR who helped me pilot test data collections and ensure things were running as smoothly as possible.

ABSTRACT

Previous research has addressed the effectiveness of attentional focus instructions in improving golf performance with a single training session. The purpose of the current study was to investigate the effect of external (EF) attentional focus instructions on recreational golfers' performance over a distributed training period and extended retention interval. Performance was measured by club head velocity (CHV) and X-factor as both have been correlated with greater performance. The current study extends the work of An, Wulf, and Kim (2013), by increasing the training period and retention interval. It was hypothesized EF group would have greater CHV and X-factor measurements during the training and retention interval compared to a control (C) group. Repeated measures ANCOVA tested for significant differences in CHV and X-factor measures between EF and C groups. No significant main effects (time or group) or interactions were found during the training period or retention tests for either CHV or X-factor. Future studies should determine if the cue used in the current study was appropriate for eliciting an improvement in performance, or if different components of the swing need to be emphasized for greater performance improvements.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

Performance improvement is a goal many individuals attempt to achieve in a variety of settings. In sports, a greater performance generally determines who wins and who loses a contest. While there are many techniques to aid in performance improvement, attentional focus is a widely used training technique that is beneficial during practice to aid performance improvement of a skill. Many studies have used golf tasks as methods to investigate the effectiveness of attentional focus techniques (An, Wulf, & Kim, 2013; Bell & Hardy, 2009; Wulf & Su, 2007). Of the studies that have used a golf task, all have resulted in externally focused instructions increasing performance. However, even with the amount of literature supporting externally focused instructions, which has been documented by Wulf (2013), there are still gaps within the literature needing to be addressed.

A gap in the literature exists in investigating the effectiveness of attentional focus instructions over a lengthened training period and retention interval. Previous motor learning studies have established externally focused attentional instructions produce greater performance outcomes compared to internally focused or no instructions (Bell & Hardy, 2009; Chiviacowsky, Wulf, & Wally, 2010; Wulf & Su, 2007). An overwhelming amount of research has been conducted over short training periods, typically lasting 1-2 days (An et al. , 2013; Bell & Hardy, 2009; Chiviacowsky et al., 2010). Recently, An et al. (2013) have supported the use of external attentional focused instructions to increase golf swing performance outcomes. However, no studies were found using attentional focus instruction on golf swing performance over a lengthened training period or extended retention interval. The current study used a combination of motor learning principles and biomechanical measurements to gain a better understanding of performance changes in recreational golfers over a lengthened training period. When the fields of biomechanics and motor learning are used together, they offer an extensive examination of how attentional focus can be used to assist golfers to achieve a greater level of performance.

Previous Research

Motor Learning

A large body of literature within the area of motor learning exists regarding attentional focused instructions (Wulf, 2013). There are two forms of attentional focus, internal and external, which are generally provided in the form of instructional cues and feedback during learning of motor tasks. Internally focused cues shift participants' focus to their body movement whereas externally focused cues shift participants' focus on the effect of the movement outcome (An et al., 2013; Chivacowsky et al., 2010; McNevin, Shea, & Wulf, 2003). The externally focused cue used by Wulf, Lauterbach and Toole(1999) in a golf task shifted participants' focus to the golf club while the internally focused cue shifted participants' focus to the swing of their arms. When compared to one another, it has been widely reported externally focused instructions produce greater performance outcomes than internally focused or no instructions (An et al., 2013; Bell & Hardy, 2009; Chiviacowsky et al., 2010; Wulf & Su, 2007).

The variety of tasks used in previous studies provides broad support of externally focused instruction's superiority over internally focused or no instructions. A few examples of tasks such as stability in older adults (Chivacowsky et al., 2010), volleyball serves (Wulf, McConnel, Gärtner, & Schwarz, 2002, experiment 1), soccer kicks (Wulf et al., 2002, experiment 2), golf putting (Poolton, Maxwell, Masters, & Raab, 2006), golf chipping (Bell & Hardy, 2009), golf pitching (Wulf & Su, 2007), and overhand throwing (Southard, 2011) have supported the use of externally focused instructions. Additionally, studies using various levels of experience with a task have also resulted with externally focused instructions eliciting greater performance outcomes compared to internally focused or no instructions (Bell & Hardy, 2009; Wulf & Su, 2007).

The evidence for externally focused instructions resulting in greater performance outcomes is supported by the constrained action hypothesis (McNevin et al., 2003). It is hypothesized when participants are provided an externally focused instruction, movement is controlled by automatic natural reflexes, thereby producing a smooth and fluid movement (McNevin et al., 2003; Wulf, McNevin, & Shea, 2001). This is different for those who are provided an internally focused cue, the natural reflexive motor system is inhibited, which leads to a less organized movement, producing a rigid and uncoordinated movement (McNevin et al., 2003; Schmidt & Lee, 2011).

Additional concepts from motor learning that greatly influence the methodologies of the current study are theories from practice scheduling and the memory consolidation hypothesis. Research in practice scheduling investigates whether participants learn better when practice trials are spaced over time (distributed practice schedule) versus practice trials spaced close together (massed practice schedule; Lee & Genovese, 1988). Until recently, conclusions supported discrete tasks, such as a golf swing, should be practiced in a massed practice schedule because fatigue will not cause mechanical flaws, as seen with continuous tasks in massed schedules (Lee & Genovese, 1988, 1989). However, recent findings within this literature suggest the level of task complexity should be considered, discrete tasks, higher in complexity should be distributed and spaced over time (Arthur et al., 2010). The memory consolidation hypothesis states when teaching multiple tasks simultaneously or with minimal rest between tasks (as experienced in a massed schedule), learning is interrupted, there is not enough time for short-term memories to be consolidated into long-term memories (Shea, Lai, Black, & Park, 2000; Shewokis, 2003). It has been suggested that a distributed practice schedule should be used for more complex tasks, despite being discrete in nature (Arthur et al., 2010).

Biomechanics

Biomechanical measurements can be used to help researchers determine if learning has occurred by quantifying movement patterns. Biomechanical measures give researchers an objective method to measure learning, instead of using movement outcomes. Previous studies (An et al., 2013) have used biomechanical measures in collaboration with motor learning training techniques, such as attentional focus. The current study used club head velocity (CHV) and X-factor as two measurements to quantify changes in performance. CHV and X-factor have been used in previous biomechanical studies, which have investigated the correlation between them (Hellström, 2009; Myers et al., 2008; Zheng, Barrentine, Fleisis, & Andrews 2008). Both CHV and X-factor are positively correlated to performance levels, thus an increase in either measure would indicate an increase performance level (Fradkin, Sherman, & Finch 2004; Myers et al., 2008).

While An et al. (2013) utilized carry distance as a means to measure performance, CHV was used in the current study. In order to achieve a greater hitting distance, an increase in CHV is needed at impact (Joyce, Burnett, Cochrane, & Ball, 2013). Further, it has been shown that higher skilled golfers hit the ball farther when compared to lower skilled golfers (Hellström, 2009; Lindsay, Mantrop, & Vandervoort, 2008; Myers et al., 2008). CHV has been validated as an applicable surrogate for hitting distance in laboratory based studies (Fradkin et al., 2004).

The X-factor is the difference in the angles of rotation between the trunk and the pelvis (Cole & Grimshaw, 2009; Myers et al., 2008). Although similar to the X-factor stretch used in previous work by An et al. (2013), the X-factor was used as a performance measure in the current study because it has been identified as a variable that directly affects CHV (Chu, Sell, & Lephart, 2010; Myers et al., 2008; Zheng et al., 2008). An increase in the X-factor leads to proper trunk rotation sequencing, which leads to proximal-to-distal sequencing of the body and its segments (Ball & Best, 2007; Chu et al., 2010; Fujimoto-Kanatani, 1996). Greater X-factor values have been noted among professionals (Cheetham, Martin, Mottram, & St. Laurent, 2001) and among players with faster ball velocities (Myers et al., 2008). Both professionals and players with faster ball velocities tend to have greater body control (e.g., more preferable muscle coordination patterns) than lower skilled or non-professional players (Hellström, 2009).

Current Study

Purpose and Hypothesis

The purpose of this study was to investigate the effect of external attentional focused instructions among recreational golfers and their performance over a lengthened training period and extended retention interval. Performance was measured by the X-factor and CHV. The current study extended the work of An et al. (2013). The training period of the current study was lengthened to four days, completing 50 trials per day. Retention tests were extended to 3, 6, and 10 days after the training period concluded. The methodological additions, such as an extended training period with spaced trial blocks, were grounded in the practice scheduling and memory consolidation hypothesis that literature (Arthur et al., 2010; Shea et al., 2000; Shewokis, 2003). It was hypothesized participants given an externally focused instruction would demonstrate greater X-factor and CHV during the training and retention interval compared to a control group (An et al., 2013; Arthur et al., 2010; McNevin et al., 2003; Wulf et al., 2001; Shea et al., 2000; Shewokis, 2003). This is one of few studies (Arthur et al., 2010) to use a lengthened training period and extended retention interval on a complex discrete task like a full golf swing.

CHAPTER II: LITERATURE REVIEW

Previous research has addressed the effectiveness of attentional focus instruction in improving golf performance with a single training session (An et al., 2013). However, a gap in the literature exists in investigating the effectiveness of attentional focus instructions on golf swing performance over a distributed training period, and a lengthened retention interval. The purpose of this study was to investigate the effect of external attentional focus instructions on recreational golfers and their performance over a distributed training period and extended retention interval. The current study used biomechanical measurements to gain a better understanding of performance level changes in recreational golfers. This review will include research from motor learning and biomechanics that support the current experimental methodology.

Motor Learning

In order to better understand how performance can be improved, as measured by club head velocity (CHV) and X-factor, the current study provided participants externally focused instructions or no instructions, over a four day period. To test for a lasting effect of changes in performance, participants underwent three delayed retention tests. The following sections include a review of literature from attentional focus, the constrained action hypothesis, practice scheduling, and the memory consolidation hypothesis.

Attentional Focus

Attentional focus instructions are given to participants as a way to shift their focus to a certain aspect of a movement. Externally focused cues shift focus to the movement outcome whereas internally focused cues shift focus to participants’ bodies (An et al., 2013; Chivacowsky et al., 2010; McNevin et al., 2003). For example, the externally focused cue used by Wulf and Su (2007) in a golf chipping study shifted participants’ focus to the “pendulum like motion” (p. 385) of the golf club, whereas the internally focused cue shifted participants’ focus to the swinging motion of their arms.

A variety of tasks have been used in previous attentional focus literature to examine whether externally focused or internally focused instructions produce greater performance outcomes: tasks such as balance (Chiviacowsky et al., 2010), a full golf swing (An et al., 2013), a golf pitch/chip (Bell & Hardy, 2009; Wulf et al., 1999; Wulf & Su, 2007), golf putting (Granados, 2010), soccer throw-in (Wulf, Chiviacowsky, Schiller, & Ávila, 2010), basketball free throw (Zachry, Wulf, Mercer, & Bezodis, 2005), and force production (e.g. pushing into a plate with a foot; Lohse, Sherwood, & Healy, 2011). Additionally, researchers have also investigated the effect of attentional focus instructions on beginners (An et al., 2013; Chiviacowsky et al., 2010; Lohse et al., 2011; Wulf et al., 1999; Wulf et al., 2010) as well as experts (Bell & Hardy, 2009; Wulf & Su, 2007). When compared to internally focused or no instructions, externally focused instructions have widely produced greater performance outcomes (Wulf, 2013). Externally focused instructions have also produced greater outcomes with special populations, such as those who have suffered a cerebrovascular accident, in reaching tasks (Fasoli, Trombly, Tickle-Degnen, & Verfaellie, 2002) and with child-aged populations (Emanuel, Jarus, & Bart, 2008). Due to the breadth of previous research, the use of externally focused instructions over internally focused instructions can be generalized across different tasks and populations. Others have manipulated the presentation order of instructions, participants receiving both externally focused and internally focused conditions (Lohse et al., 2011; Zachry et al., 2005), and still performance is enhanced when provided external focus.

Specifically related to the current study, An and colleagues (2013) investigated the effect of attentional focused instructions on the golf swing performance of beginner golfers. They had three groups of attentional focus conditions: an externally focused group, an internally focused group, and a control group; all participants were right handed. The externally focused group received the cue “push against the left side of the ground as you hit the ball”; the internally focused group received the cue “transfer your weight to your left foot as you hit the ball”; the control group did not receive attentional focus instructions. All participants underwent a pre-test, a one day acquisition period (4 trial blocks of 25 trials) and a retention test three days after the acquisition period. It was concluded the externally focused group performed significantly better than both the internally focused and control group through the acquisition period and the retention test.

The constrained action hypothesis, proposed by Wulf et al. (2001) helps explain why externally focused instructions have widely produced greater results compared to internally focused instructions. When a participant is provided an internally focused cue, they will try to consciously control their movements, this will lead to an inhibition of automatic motor control (McNevin et al., 2003; Wulf et al., 2001). Doing so could produce an uncoordinated-looking movement pattern (Schmidt & Lee, 2011). For instance, the internally focused instruction used by An et al. (2013) was “transfer your weight to your left foot as you hit the ball”. Participants given this instruction may have focused much attention on their foot where they intervened in the automatic motor processes and consciously controlled their movements. Doing so increased attentional-capacity demands that may have caused “micro-choking episodes,” resulting in a very rigid and jerky movement rather than a smooth and fluid movement (Wulf, 2013, p. 91).

It is proposed that an externally focused cue reduces the amount of conscious intervention of movement control by participants and allows for a natural reflexive, rather than voluntary, control process to organize the movement (Wulf et al., 2001). An externally focused instruction should allow the movement to be more fluid and look more coordinated, since attentional-capacity demands are low (McNevin et al., 2003)

Practice Schedule

From practice scheduling literature, there is support for the use of a distributed practice schedule for a complex discrete task, like the golf swing (Arthur et al., 2010). A distributed practice schedule spreads practice trials over days, completing fewer trials per day, compared to massed practice, where more practice trials are completed in a condensed session (Lee & Genovese, 1988, 1989). An important aspect of practice scheduling literature is the ratio of time spent in practice versus the amount of time spent in rest. A distributed practice schedule allows for more rest between practice sessions, whereas massed practice allows for a greater amount of practice time.

It has been widely accepted for many years that discrete tasks such as a golf swing had greater performance improvements in massed practice (e.g., many trials completed in a single session), whereas continuous skills (e.g., riding a bike, running, swimming) were thought to have increased performance gains in a distributed practice schedule (Lee & Genovese, 1988, 1989). It has been thought that fatigue will be induced based on the continuous nature of the task. Once the onset of fatigue occurs, it is argued participants do not use proper technique to complete the task (Lee & Genovese, 1988, 1989).

More current literature supports spacing practice across multiple days (e.g., distributed practice) for complex discrete skills producing greater improvements in performance during acquisition and retention intervals (Arthur et al., 2010; Donovan & Radosevich, 1999; Shea et al., 2000). A meta-analysis performed by Donovan and Radosevich (1999) revealed previous studies reporting discrete tasks that are best learned in a massed practice schedule used simple tasks such as tapping or keyboard striking tasks. The authors concluded more complex tasks require greater rest periods to benefit learning, and the more complex the task, a greater rest interval is needed. Additional findings from more current literature suggest distributed practice has a greater lasting effect on complex skills (Arthur et al., 2010; Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006).

Arthur et al. (2010) used a complex computer based, real-time micro-simulation task examining the effectiveness of two types of practice schedules on performance at the end of the practice schedule and an eight week retention interval. Both practice schedules were distributed, with one schedule having shorter rest intervals where participants practice 10 hours over one week. The second schedule had participants practice for 10 hours over two weeks. Participants in the long rest interval group had greater performance levels after the practice period than the shorter rest interval. After an eight week retention interval, the long rest interval group also maintained greater performance levels than the shorter interval group. Based on those findings, the current study used an expanded practice schedule.

The memory consolidation hypothesis offers an explanation for the benefits of a distributed practice schedule. The memory consolidation hypothesis (MCH) states teaching two tasks simultaneously or with minimal rest between tasks may impede learning, rest is needed to facilitate memories to be transferred from short-term to long-term memory storages (Shea et al., 2000; Shewokis, 2003). Shea et al. (2000) performed an experiment where two groups completed key-press timing tasks. One group was given multiple tasks to perform in one day, where the second group received variations of the task across multiple days. The authors concluded the group with task variations spaced across days performed better during the acquisition period (three days) and at retention one day later. The MCH suggests that retention of performance over distributed practice schedule will be greater due to the rest time between practice sessions (Arthur et al., 2010; Shea et al., 2000). In the current study, the practice schedule is being spaced over multiple days where rest should aid in memory consolidation, and thus lead to greater performance levels through the retention interval.

Within the motor learning literature, there is a lack of research using extended training and retention intervals. Much of the research includes training periods that last one day (Bell & Hardy, 2009; Chiviacowsky et al., 2010; Poolton et al., 2006; Wulf & Su, 2007). In many instances, retention tests were one day later (Chiviacowsky et al., 2010; Emanuel et al., 2008; Poolton et al., 2006; Shea & Wulf, 1999; Wulf et al., 2010; Wulf, Höß, & Prinz, 1998, experiment 1; Wulf et al., 1999; Wulf & Su, 2007). This leads to questions about whether a skill was actually learned, which is measured by how well the skill is retained. In practical settings, if skills or performance is increased in the short term, yet quickly forgotten, is that a truly effective way to teach?

An et al. (2013) used a practice schedule that consisted of four trial blocks of 25 trials in a single day. The current study expanded the practice schedule to a distributed schedule of five trial blocks of 10 trials over four days. Additionally, the current study used an extended retention interval to examine a lasting effect of performance levels. Due to the findings of Arthur and colleagues (2010) in collaboration with the constrained action hypothesis, it is hypothesized for the current study the externally focused group will exhibit a greater lasting effect than the control group.

Biomechanics

The current study includes components of not only motor learning but biomechanics as well. Club head velocity (CHV) and X-factor were used as biomechanical measures of performance during acquisition and retention interval. The following sections include supporting literature for the use of X-factor and CHV as measures of performance.

CHV and X-Factor

Higher skilled golfers hit the ball farther when compared to lower skilled golfers (Hellström, 2009; Lindsay et al., 2008; Myers et al., 2008). CHV has been validated by Fradkin et al. (2004) as an applicable surrogate for hitting distance for laboratory based studies as it has been widely used in many previous studies as a performance measure

(Chu et al., 2010; Doan, Newton, Kwon, & Kraemer, 2006; Hume, Keogh, & Reid, 2005). Therefore, CHV was used as a performance measure in the current study.

The X-factor has drawn attention in recent research due to its potential effect on CHV (An et al., 2013; Cheetham et al., 2001; Chu et al, 2010; Joyce, Burnett, & Ball, 2010; Joyce et al., 2013; Myers et al., 2008; Zheng et al., 2008). X-factor is measured at the transition between the backswing and the downswing and is measured by the difference of rotation between the trunk and the pelvis (Burden, Grimshaw, & Wallace, 1998; Cheetham et al., 2001; Cole & Grimshaw, 2009; Hume et al., 2005; Myers et al., 2008). Chu and colleagues (2010) found the X-factor and rotational velocity of the pelvis at the top of the backswing accounts for 44% of the variance of golf ball velocity at impact.

If the X-factor is increased, more energy will be stored in the trunk due to a stretch-shortening cycle (Hellström, 2009; Myers et al., 2008; Zheng et al., 2008a). The pelvis is the catalyst that begins the downswing and results in an increase in the separation of rotation between the trunk and the pelvis. Doing so creates a stretch-shortening cycle (Hellström, 2009; Myers et al., 2008). A stretch-shortening cycle directly influences CHV based on the summation of forces principle, which induces proximal to distal sequencing of segment velocities of the body (Ball & Best, 2007; Fujimoto-Kanatani, 1996). Body segments achieve a higher angular velocity the further away from the pelvis (Ball & Best, 2007; Fujimoto-Kanatani, 1996; Hellström, 2009; Tinmark, Hellström, Halvorsen, & Thorstensson, 2010). The golf club head should have the greatest velocity of any segment since it is the furthest away from the pelvis (Ball & Best, 2007, Fujimoto-Kanatani, 1996; Tinmark et al., 2010). Based on the summation of forces and proximal-to-distal sequencing principles, energy will then be transferred into the club during downswing, which will lead to an increased CHV and hitting distance (An et al., 2013; Joyce et al., 2010; Myers et al., 2008).

Based on the principles of a stretch-shortening cycle and summation of forces, if there is an increase in participants' X-factor, an increase in CHV should follow. Since CHV is linked to performance level, an increased X-factor should be linked to an increased performance level (Fradkin et al., 2004; Myers et al., 2008; Zheng et al., 2008). Although the X-factor is just one of multiple variables which affect performance it initiates the downswing and promotes the proximal-to-distal sequencing of body segments (Ball & Best, 2007; Fujimoto-Kanatani, 1996). Since the golf club is the most distal segment of the movement, it will have the greatest velocity, which in turn will lead to an increase in performance (Chu et al., 2010).

Another limitation in the research has been multiple ways of capturing data to calculate the X-factor (Hellström, 2009). Studies that did not find the X-factor to be positively correlated with CHV used a capture method where markers were placed medially, towards the spine of participants (Cheetham et al., 2001). Studies that found a positive correlation between CHV and the X-factor used marker configurations where the acromion processes (bony landmark on the most lateral superior aspect of the trunk just above the glenohumeral joint) were used to model the trunk (Hellström, 2009). Placing markers medially does not account for the combination of spinal axial rotation and movement of the left shoulder girdle at the top of the backswing (Hellström, 2009). However, placing markers laterally incorporates spinal axial rotation, protraction of the left shoulder girdle, and retraction of the right shoulder girdle at the top of the back swing

(Hellström, 2009). Movement of the acromion processes due to protraction and retraction may not give an accurate measurement of the X-factor, since they do not move rigidly with the trunk (Myers et al., 2008). With conflicting reports, the current study used a medial device configuration because it is a much more appropriate indicator of trunk rotation as opposed to movement of the acromion processes (Myers et al., 2008).

Conclusion

The purpose of the study is to investigate the effect of attentional focus instructions on recreational golfers and their performance. Externally attentional focused instructions should aid participants in the current study in performance level enhancement based on the supporting breadth of literature documented by Wulf (2013). Evidence supporting the use of a distributed practice schedule will further assist participants in the externally focused group in improving in performance level relative to the control group (Arthur et al., 2010; Shea et al., 2000). The X-factor is important because of the positive correlation with CHV. Since CHV is directly linked to performance level, if a golfer increases their X-factor, an improvement in performance should follow (Fradkin et al., 2004).

The use of multiple disciplines, such as motor learning and biomechanics, allows researchers to gain a greater perspective on golf swing performance. A continuing collaborative research effort is needed between biomechanics and motor learning fields to gain a deeper understanding into the nuances of how golf swing performance level can successfully be improved.

CHAPTER III: METHODS

The purpose of this study was to investigate the effects of external attentional focus instructions on recreational golfers and their performance. Performance was evaluated using X-factor and club head velocity (CHV). It was hypothesized participants in an externally focused instruction group would exhibit greater X-factor and CHV measurements compared to a control group through a four day training period and three delayed retention tests (An et al., 2013; Arthur et al., 2010; McNevin et al., 2003). The following sections will include a description of the participants, the task, testing procedures, and finally a description of the variables examined in this study.

Participants

Local golfers and students from a Northwest university were recruited for this study. In order to participate, participants were required to meet specific inclusion criteria. Inclusion criteria for the current study was: being between the ages of 18 and 50 (the minimum age limit for the Professional Golf Associates Championship Tour), ability to attend the 7 data collection sessions, bring their own clubs, and play less than two rounds of golf per month. If prospective participants failed to meet any of those criterions, they were excluded from participation.

Task

The research study took place at a Northwest university's biomechanics laboratory. Participants were asked to hit golf balls off an octagon shaped astro-turf mat

(1.47 m diameter) using a driver into a net. The net was located 3.2 m away from the edge of the mat. General instructions were provided to all participants ("act as if you are hitting the ball as far and as straight as possible").

Figure 1: Inertial Measurement Unit

Instrumentation

An 8 camera Vicon Nexus system (Vicon Motion Systems Ltd., United Kingdom) was used to capture CHV by a three retro-reflective marker cluster on the golf club head. The cameras capture rate was 120 frames per second. CHV data were analyzed in Visual 3D analysis software (C-Motion Inc., Maryland, USA).

X-factor was captured by two inertial measurement unit sensors (IMU; Figure 1; InterSense, Massachusetts, USA) placed on the trunk and sacrum. A total of seven IMUs were attached to participants via Velcro belts except for the sensor on the trunk, which was placed in an elastic backpack (Figure 2). The additional sensors were placed on the head and bilaterally on the upper and lower arms allowing for a single model to accommodate both right and left handed golfers. The sampling rate for the IMUs was 180 Hz. Data collected from the IMUs were analyzed through MotionMonitor Toolbox (Illinois, USA).

Figure 2: IMU devices on participant

Additionally, two in-ground force plates (Kistler, New York, USA), were used to collect ground reaction force data (2400 Hz) for an objective manipulation check for the externally focused (EF) group. Participants were standing with one foot on each plate. Resultant peak ground reaction forces (GRF) of the lead leg were calculated for the pre-test and training period trials.

Experimental Protocol

Data collection for each participant took place on seven days over a three week period. Participants were encouraged not to practice golf in between training period days or in between retention days. All participants underwent a pre-test, a four day consecutive training period, and three delayed retention tests at days 3, 6, and 10 following the training period (Figure 3). All data collection days followed the same procedures; participants were outfitted with IMUs upon arrival, a warm-up that consisted of hitting golf balls off the mat until comfortable, then once comfortable participants were given general instructions of “act as if you are hitting the ball as far and as straight as you can.”

Following these instructions participants were then provided an overview for the day (e.g., number of trials to be completed). Participants would then begin their training period (5 blocks of 10 trials each day) or retention tests (1 block of 10 trials).

Table 1:
Representative study schedule

		Day 1: Pre-test Training period day 1	Day 2: Training period day 2	Day 3: Training period day 3	Day 4: Training period day 4	
	Day 5: Retention day 1			Day 6: Retention day 2		
	Day 7: Retention day 3					

The first day of the study included the pre-test (with no attentional focused instruction) followed by the first training period day. Attentional focus instructions were given to the EF group during the two minute rest break after the pre-test, and repeated after every trial. Since all EF participants were right handed, the instruction was the same, “push against the left side of the ground as you hit the ball” (An et al., 2013); the control (C) group received no instruction. The EF group was asked, at the end of each trial to give a percentage to which they adhered to the instruction. This was self-report manipulation check to determine if participants focused their attention appropriately (An et al., 2013). Resultant peak GRF generated by the lead foot were calculated by data collected from the force plates and served as an objective manipulation check. The externally focused cue intended to focus participants’ attention to push with more force through their front foot.

Training days two through four followed a similar protocol to day one, with the exception of the pre-test. Each training day consisted of five trial blocks of 10 trials for 50 total trials each day. The EF group continued to receive the externally focused instruction after every trial through these three days. Participants continued to self-report their adherence rate and force plate manipulation checks were still collected. Three, six, and 10 days after the training period, participants underwent a retention test each of those days (Table 1).

All three retention tests consisted of one block of 10 trials each. No attentional focus instructions were given during the retention tests, however, the general instruction of “act as if you are hitting the ball as far and as straight as you can” was still provided as a reminder. The retention tests followed the same protocol as the training period, participants would be outfitted with the IMUs and would warm-up until comfortable, then data collection would begin.

Variables and Data Analysis

Data were reduced using methods similar to that of An et al. (2013). The number of trials used for analysis was reduced to the top five CHV speeds for the pre-test and retention tests for each participant. For the training period, trials were reduced to the top CHV per block per participant (five total trials per day) and were used for further analysis. CHV was determined as the peak velocity at the bottom of the downswing. The X-factor was calculated for the corresponding trials. The following sections contain detailed information regarding 1) how manipulation check data were analyzed and reported; 2) methods used to filter, compute and analyze CHV and X-factor data; and 3) the statistical test used to check for significance.

Dependent Variables

Prior to calculating CHV, data collected from the Vicon Nexus system were filtered with a bidirectional Butterworth filter with a cutoff frequency set at 6 Hz. Peak CHV was calculated for comparisons. CHV values from the training period and retention tests were compared to the five pre-test trials with the highest CHV values.

The X-factor value was calculated as the axial rotation of the trunk relative to the pelvis at the top of the backswing. Top of the backswing was determined as the highest position of the left wrist IMU, similar to An and colleagues (2013). The IMUs placed on the trunk and sacrum were used to measure the position of the trunk and pelvis, respectively. Although previous studies have used the address position (the time period prior to the start of the backswing) as a global zero, the current study allowed any trunk and/or pelvis rotation at the address position as it still affects the X-factor (Myers et al., 2008).

For the self-reported manipulation check, EF participants were asked to give a percentage to which they adhered to the externally focused instruction for all of the training period days, similar to An et al. (2013). Those percentages were then calculated as group means and standard deviations for each day of the training period.

For the second manipulation check involving force plates, data were filtered with a bidirectional, low-pass Butterworth filter with a cutoff frequency set at 25 Hz. Resultant peak GRF from each training period trial was compared to the average peak GRF of the pre-test trials. GRFs were normalized to participants' body weight. Training period force production was compared to the pre-test force production and represented as a percentage of the force produced from the pre-test.

Statistical Analysis

CHV and X-factor data were analyzed separately. Training period data for the X-factor and CHV were analyzed with 2 (Group; EF and C) × 4 (training period days) repeated measures ANCOVA. Retention data for both variables were analyzed with 2 (Group) × 3 (retention interval day) repeated measures ANCOVA. The pre-test data for X-factor and CHV were used as covariates for all corresponding analyses, which controlled for variance in performance level prior to receiving (EF group) or not receiving (C group) attention focus instructions.

CHAPTER IV: RESULTS

It was hypothesized the EF group would exhibit greater X-factor and CHV measurements than the control through the training period (McNevin et al., 2003). It was also hypothesized that participants in the EF group would have a higher performance level through retention tests (Arthur et al., 2010). Two separate repeated measures ANCOVA was used to test for statistical significance between groups and between testing days for X-factor and CHV during the training period and retention testing. X-factor and CHV pre-test data were used as the covariates for the corresponding analyses.

Participants

Ten individuals participated in the study, however technical issues with the data set from one participant made their data unusable. Participant demographics are presented in Table 2.

Table 2:
Patient Demographics for EF and C groups

	EF (n = 4)	C (n = 5)
	M (*SD*)	*M* (*SD*)
Age	34 yrs (11.22)	27.8 yrs (5.36)
Golf Experience	9.25 yrs (4.66)	12.2 yrs (8.76)

X-Factor

Repeated measures ANCOVA Training period testing day main effect, F (1, 7) = 1.625, η^2 = 0.494 and group main effect, F (1, 7) = 1.646, η^2 = 0.19 were not significant. Retention interval testing day main effect, F (1, 7) = 0.917, η^2 = 0.234 and group main effect, F (1, 7) = 0.037, η^2 0.005 were not significant. Mean values for X-factor measurements for the EF and C group are presented in Figure 3. Means and standard deviations are presented in Table 4. A greater negative value means a greater X-factor, or more rotation of the trunk relative to the pelvis.

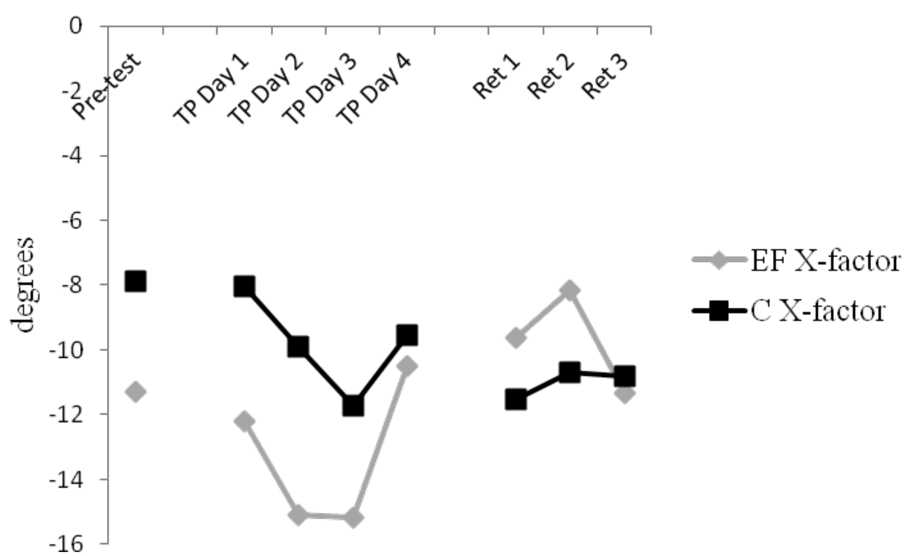

Figure 3: Raw X-factor measurements for EF and C groups for the pre-test, training period (TP) and retention test (Ret)

Table 4:
X-factor Measurements for EF and C Groups

	X-factor	
	EF group	C group
	M(*SD*)	M(*SD*)
Pre-test	-11.295 (4.35)	-7.875 (6.55)
Training Period Day 1	-12.1875 (4.53)	-8.03 (5.45)
Training Period Day 2	-15.112 (5.44)	-9.894 (5.72)
Training Period Day 3	-15.166 (5.29)	-11.734 (7.55)
Training Period Day 4	-10.506 (3.13)	-9.527 (7.23)
Retention Day 1	-9.617 (5.90)	-11.536 (6.20)
Retention Day 2	-8.152 (5.06)	-10.700 (3.65)
Retention Day 3	-11.314 (4.12)	-10.794 (3.18)

Measurements are in degrees; negative means more rotation

CHV

CHV results are presented in Figure 4. For the training period, main effects for training day ($F\ (1,7) = 0.32$, $\eta^2 = 0.161$) and group ($F\ (1, 7) = 0.141$, $\eta^2 = 0.002$) were not significant; interactions were also not significant. For the retention interval, main effects for training day ($F\ (1, 7) = 0.869$, $\eta^2 = 0.225$) and group ($F\ (1, 7) = 0.369$, $\eta^2 = 0.05$). Means and standard deviations are presented in Table 5.

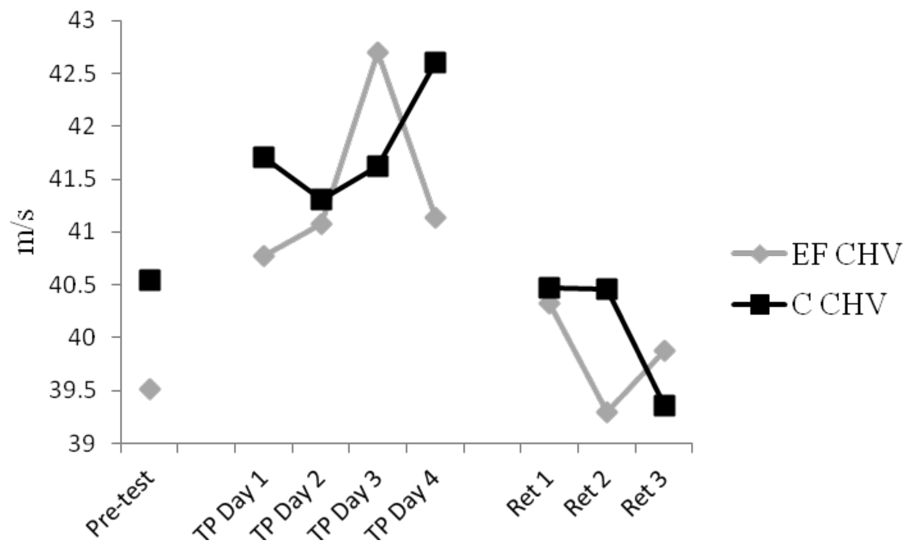

Figure 4: Raw CHV data for EF and C groups for pre-test, training period (TP), and retention tests (Ret)

Table 5:
Club Head Velocity Measurements for EF and C Groups

	CHV	
	EF group	C group
	M(*SD*)	M(*SD*)
Pre-test	39.518 (4.35)	40.544 (6.31)
Training Period Day 1	40.770 (4.53)	41.706 (6.08)
Training Period Day 2	41.081 (4.84)	41.308 (5.31)
Training Period Day 3	42.704 (2.53)	41.626 (5.33)
Training Period Day 4	41.140 (3.96)	42.599 (5.34)
Retention Day 1	40.330 (4.35)	40.476 (5.09)
Retention Day 2	39.296 (4.31)	40.455 (5.09)
Retention Day 3	39.881 (4.48)	39.361 (5.79)

Measurements are in m/s

Manipulation Check

Two manipulation checks were used to determine EF group's adherence to the externally focused instruction of "push against the left side of the ground as you hit the ball.” The intent of the cue was for participants to push into the ground with their lead foot, which would lead to a greater production of force. Means and standard deviations for the self-reported adherence can be found in Table 6.

Table 6:
EF Group Self-reported Manipulation Check

	Training Period			
	Day 1	Day 2	Day 3	Day 4
	M (SD)	*M* (*SD)*	*M* (*SD*)	*M* (*SD*)
Percentage of adherence	83.65 (10.74)	86.70 (10.59)	85.15 (16.83)	83.69 (12.87)

Data from the objective manipulation check, force plates, are presented in Table 7. The values in Table 7 represent the percentage of force during each day of the training period compared to the amount force generated during the pre-test. For example, the group average force generated on Day 1 was 1.34 Newtons · body weight $(BW)^{-1}$, which is 103.8% of the average force generated during the pre-test (1.29 N · BW^{-1}).

Table 7:
Percentages of Force Generated by the Lead Foot

	Training Period			
	Day 1	Day 2	Day 3	Day 4
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Newtons · BW^{-1}	1.43 (0.37)	1.42 (0.44)	1.44 (0.56)	1.47 (0.45)
Percentage	103.8	110.3	112.0	113.9

Missing Data

Two participants (one participant from each group) missed the third day of the training period, and another missed the final retention test. No participant missed more than one day. For all participants, the previous day's data was used to fill the missing data (Peugh & Enders, 2004). In addition, a separate repeated measures ANCOVA was conducted with means of the day prior and after the missed day to ensure the results were not different. Statistical results were not affected by using the previous day's data compared to the mean of the day prior and after the missed day. No significance was found with either method: for CHV with the previous day's data $p = 0.233$; for CHV with the day prior and after mean $p = 0.718$; for X-factor with the previous day's data $p = 0.152$; for X-factor with the day prior and after mean $p = 0.449$. A third participant, from the control group, missed the third retention test. Repeated measures ANCOVA was used with an average of the first and second day's data and with the second day's data filling the missing data for this particular participant. There was no statistical difference with either method (for CHV with the day prior and after mean $p = 0.640$; CHV with previous day's data $p = 0.688$; X-factor with the day prior and after mean $p = 0.141$; X-factor with previous day's data $p = 0.152$). Lastly, due to technical issues another participant's (EF group) pre-test X-factor data was not useable. This participant's data were not used in any analysis since pre-test data were the covariate for all analyses

Conclusion

Results from both manipulation checks suggest that participants in the EF group did adhere to their instruction to a high degree. For all training period days, their percentage of force generated was over 100% of the pre-test force values and the verbal manipulation check averaged nearly 85% over the same duration. However, statistical analyses of the performance variables, X-factor and CHV, revealed no statistical difference between EF and C groups or between training period or retention interval days.

Even with a high degree of adherence to the instruction, the EF group did not demonstrate marked improvement over the C group.

REFERENCES

An, J., Wulf, G., & Kim, S. (2013). Increased carry distance and x-factor stretch in golf through an external focus of attention. *Journal of Motor Learning and Development*, *1*, 2-11.

Arthur, W., Day, E., Willado, A .J., Boatman, P. R., Kowollik, V., Bennett, W., & Bhupatkar, A. (2010). The effect of distributed practice on immediate posttraining, and long-term performance on a complex command-and-control simulation task. *Human Performance, 23*(5), 428-445.

Ball, K. A., & Best, R. J. (2007). Different centre of pressure patterns within the golf stroke II:Group-based analysis. *Journal of Sports Sciences, 25*(7), 771-779.

Bell, J. J., & Hardy, J. (2009). Effects of attentional focus on skilled performance in golf. *Journal of Applied Sport Psychology, 21*(2), 163-177.

Burden, A. M., Grimshaw, P. N., & Wallace, E. S. (1998). Hip and shoulder rotations during the golf swing of sub-10 handicap players *Journal of Sports Sciences*, *16*(2), 165-176.

Cepeda, N. J., Pashler, H., Vul, E., Wixted, J. T., & Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin*, *132*(3), 354.

Cheetham, P. J., Martin, P. E., Mottram, R. E., & St Laurent, B. F. (2001). The importance of stretching the “X-Factor” in the downswing of golf: The “X-Factor Stretch.” *Optimising Performance in Golf*, 192-199.

Chiviacowsky, S., Wulf, G., & Wally, R. (2010). An external focus of attention enhance balance learning in older adults. *Gait & Posture*, *32*(4), 572-575.

Chu, Y., Sell, T. C., & Lephart, S. M. (2010). The relationship between biomechanical variables and driving performance during the golf swing. *Journal of Sports Sciences*, *28*(11), 1251-1259.

Cole, M. H., & Grimshaw, P. N. (2009). The X-factor and its relationship to golfing performance. *Journal of Quantitative Analysis in Sports*, *5*(1), 1-19.

Doan, B. K., Newton, R. U., Kwon, Y., & Kraemer,W. J. (2006). Effects of physical conditioning on intercollegiate golfer performance. *Journal of Strength and Conditioning Research, 20*, 62–72.

Donovan, J. J., & Radosevich, D. J. (1999). A meta-analytic review of the distribution of practice effect: Now you see it, now you don't. *Journal of Applied Psychology*, *84*(5), 795.

Emanuel, M., Jarus, T., & Bart, O. (2008). Effect of focus of attention and age on motor acquisition, retention, and transfer: A randomized trial. *Physical Therapy*, *88*(2), 251-260.

Fasoli, S. E., Trombly, C. A., Tickle-Degnen, L., & Verfaellie, M. H. (2002). Effect of instructions on functional reach in persons with and without cerebrovascular accident. *The American Journal of Occupational Therapy, 56*(4), 380-390.

Fradkin, A. J., Sherman, C. A., & Finch, C. F. (2004). How well does club head speed correlate with golf handicaps?. *Journal of Science & Medicine in Sport*, *7*(4), 465-472.

Fujimoto-Kanatani, K. K. (1996). *Determining the essential elements of golf swings used by elite golfers* (Unpublished doctoral dissertation). Oregon State University, Corvallis, Oregon.

Granados, C. (2010). Effects of observation, dialogue, and attentional focus indyadic training protocol. Unpublished Master's thesis, University of Nevada, Las Vegas.

Healy, A., Moran, K. A., Dickson, J., Hurley, C., Smeaton, A. F., O'Connor, N. E., & … Chockalingam, N. (2011). Analysis of the 5 iron golf swing when hitting for maximum distance. *Journal of Sports Sciences*, *29*(10), 1079-1088.

Hellström, J. (2009). Competitive elite golf. *Sports Medicine*, *39*(9), 723-741.

Higdon, N.R., Finch, W., Leib, D., & Dugan, E. L. (2012). Effects of fatigue on golf performance. *Sports Biomechanics, 11*(2), 190-196.

Hume, P. A., Keogh, J., & Reid, D. (2005). The role of biomechanics in maximizing distance and accuracy of golf shots. *Sports Medicine, 35*(5), 429-449.

Joyce, C., Burnett, A., & Ball, K. (2010). Methodological considerations for the 3D measurement of the X-factor and lower trunk movement in golf. *Sports Biomechanics, 9*(3), 206-221.

Joyce, C., Burnett, A., Cochrane, J., & Ball, K. (2013). Three-dimensional trunk kinematics in golf: between-club differences and relationships to clubhead speed. *Sports Biomechanics*, *12*(2), 108-120.

Lee, T. D., & Genovese, E. D. (1988). Distribution of practice in motor skill acquisition: Learning and performance effects reconsidered. *Research Quarterly for Exercise & Sport, 58*(4), 277-287.

Lee, T. D., & Genovese, E. D. (1989). Distribution of practice in motor skill acquisition: different effects for discrete and continuous tasks. *Research Quarterly for Exercise & Sport, 60*(1), 59-65.

Lindsay, D. M., Mantrop, S., & Vandervoort, A. A. (2008). A review of biomechanical differences between golfers of varied skill levels. *International Journal of Sports Science &Coaching, 3*(0), 187-197.

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2011). Neuromuscular effects of shifting the focus of attention in a simple force production task. *Journal of Motor Behavior*, *43*(2), 173-184.

McNevin, N. H., Shea, C. H., & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research, 67*, 22-29.

Myers, J., Lephart, S., Tsai, Y., Sell, T., Smoliga, J., & Jolly, J. (2008). The role of upper torso and pelvis rotation in driving performance during the golf swing. *Journal of Sports Sciences*, *26*(2), 181-188.

Peugh, J. L., & Enders, C. K. (2004). Missing data in educational research: A review of reporting practices and suggestions for improvement. *Review of educational research*, *74*(4), 525-556.

Poolton, J. M., Maxwell, J. P., Masters, R. W., & Raab, M. M. (2006). Benefits of an external focus of attention: Common coding or conscious processing? *Journal of Sports Sciences*, *24*(1), 89-99.

Schmidt, R. A., & Lee, T. D. (2011). Motor control and learning a behavioral emphasis. (5th ed., pp. 452-454). Champaign, IL: Human Kinetics.

Shea, C. H., Lai, Q. Q., Black, C. C., & Park, J. H. (2000). Spacing practice sessions across days benefits the learning of motor skills. *Human Movement Science,19* (5), 737-760.

Shea, C H., & Wulf, G. (1999). Enhancing motor learning through external-focus instructions and feedback. *Human Movement Science*, *18*, 553-571.

Shewokis, P. A. (2003). Memory consolidation and contextual interference effects with computer games. *Perceptual & Motor Skills, 97*(2), 581-589.

Southard, D. (2011). Attentional focus and control parameter: Effect on throwing pattern and performance. *Research Quarterly for Exercise & Sport*, *82*(4), 652-666.

Tinmark, F., Hellström, J., Halvorsen, K., & Thorstensson, A. (2010). Elite golfers' kinematic sequence in full-swing and partial-swing shots. *Sports Biomechanics, 9*(4), 236-244.

Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport & Exercise Psychology*, *6*(1), 77-104.

Wulf, G., Chiviacowsky, S., Schiller, E., & Ávila, L. T. G. (2010). Frequent external focus feedback enhances motor learning. *Frontiers in psychology*, *1*, 190.

Wulf, G., Höß, M., & Prinz, W. (1998). Instructions for motor learning: differential effects of internal versus external focus of attention. *Journal of Motor Behavior, 30*, 169-179.

Wulf, G. G., Lauterbach, B. B., & Toole, T. T. (1999). The learning advantages of an external focus of attention in golf. / Avantages, pour l'apprentissage du golf, d'une attention focalisee sur l'effet de l'action. *Research Quarterly for Exercise & Sport*, *70*(2), 120-126.

Wulf, G., McConnel, N., Gärtner, M., & Schwarz, A. (2002). Enhancing the learning of sport skills through external-focus feedback. *Journal Of Motor Behavior*, *34*(2), 171-182.

Wulf, G., McNevin, N.H., & Shea, C.H. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *Quarterly Journal of Experimental Psychology 54A*, 1143-1154.

Wulf, G., & Su, J. (2007). An external focus of attention enhances golf shot accuracy in beginners and experts. *Research Quarterly For Exercise & Sport*, *78*(4), 384-389.

Zachry, T., Wulf, G., Mercer, J., & Bezodis, N. (2005). Increased movement accuracy and reduced EMG activity as the result of adopting an external focus of attention. *Brain Research Bulletin*, *67*(4), 304-309.

Zheng, N. N., Barrentine, S. W., Fleisig, G. S., & Andrews, J. R. (2008). Kinematic analysis of swing in pro and amateur golfers. *International Journal Of Sports Medicine*, *29*(6), 487-493.

APPENDIX

The Effect of Attentional Focus Instruction on Golf Swing Performance in Recreational Golfers

Manuscript for submission to the *Journal of Sports Biomechanics*

Jeffrey Eggleston: Boise State University, 1910 University Dr., Boise, ID 83725; jeffreyeggleston@u.boisestate.edu

Eric L. Dugan (corresponding author): Boise State University, 1910 University Dr., Boise, ID 83725; ericdugan@boisestate.edu; (208) 426-3512

Laura J. Petranek: Boise State University, 1910 University Dr., Boise, ID 83725; laurajonespetranek@boisestate.edu; (208) 426-4366

Abstract

Previous research has addressed the effectiveness of attentional focus instructions in improving golf performance with a single training session. The purpose of the current study was to investigate the effect of external (EF) attentional focus instructions on recreational golfers' performance over a distributed training period and extended retention interval. Performance was measured by club head velocity (CHV) and X-factor as both have been correlated with greater performance. The current study extends the work of An, Wulf, and Kim (2013), by increasing the training period and retention interval. It was hypothesized EF group would have greater CHV and X-factor measurements during the training and retention interval compared to a control (C) group. Repeated measures ANCOVA tested for significant differences in CHV and X-factor measures between EF and C groups. No significant main effects (time or group) or interactions were found during training period or retention tests for either CHV or X-factor. Future studies should determine if the cue used in the current study was appropriate for eliciting an improvement in performance, or if different components of the swing need to be emphasized for greater performance improvements.

Keywords: externally focused instruction, X-factor, club head velocity

Introduction

Previous motor learning studies have established externally focused attentional instructions produce greater performance outcomes over short training periods compared to internally focused or no instruction groups (Bell & Hardy, 2009; Chiviacowsky, Wulf, & Wally, 2010; Wulf & Su, 2007). Additionally, externally focused instructions have led to greater improvements in golf swing performance compared to internally focused and no instructions (An et al., 2013). However, a gap in the literature exists in investigating the effectiveness of attentional focus instructions on golf swing performance over a lengthened training period and retention interval. The current study used a combination of motor learning principles and biomechanical measurements to gain a better understanding of performance changes in recreational golfers due to externally focused instruction.

Recent findings from the practice scheduling literature and the memory consolidation hypothesis suggest greater learning occurs, for more complex skills like the golf swing, if practice is spaced over days (Arthur et al., 2010; Shea, Lai, Black, & Park, 2000). Practice scheduling and memory consolidation theories support a distributed practice schedule, practice trials spaced over days, elicits greater performance improvements during practice in complex tasks compared to a massed practice schedule (Arthur et al., 2010; Shea et al., 2000; Shewokis, 2003). Along with greater performance improvements during practice, a greater lasting effect of performance has also been found in longer retention intervals (Arthur et al., 2010). It was previously thought that discrete skills were best learned in a massed practice schedule, while continuous skills were best learned in a distributed practice schedule (Lee & Genovese, 1988, 1989). While a golf swing is considered a discrete skill, it is also a complex skill, thus spacing practice sessions may be beneficial (Arthur et al., 2010).

A breadth of literature exists concluding that externally focused instructions produce greater performance-level enhancements relative to internally focused or no instruction (An et al., 2013; Bell & Hardy, 2009; Chiviacowsky et al., 2010; Lohse, Sherwood, & Healy, 2011; Wulf, 2013; Wulf, Chiviacowsky, Schiller, & Ávila, 2010;

Wulf, Lauterbach, & Toole, 1999; Wulf & Su, 2007; Zachry, Wulf, Mercer, & Bezodis, 2005). These results have been explained by the constrained action hypothesis (Wulf, McNevin, & Shea, 2001). The hypothesis states that externally focused instructions allow for movements to be organized by natural reflexes, whereas internally focused instructions inhibit natural motor control processes (Wulf et al., 2001).

Specifically relating to the current study, An and colleagues (2013) investigated the effect of attentional focus instructions on golf swing performance of beginning golfers. They included three groups of attentional focus conditions: an externally focused group, an internally focused group, and a control group. The externally focused group received the cue “push against the left side of the ground as you hit the ball”; the internally focused group received the cue “transfer your weight to your left foot as you hit the ball”; the control group did not receive attentional focus instructions. All participants underwent a pre-test, a training period (4 trial blocks of 25 trials), and a retention test three days after the acquisition period. The authors concluded the externally focused group significantly performed better than both the internally focused and control group through the acquisition period and the retention test.

Although An et al. (2013) utilized carry distance and X-factor stretch as a means to measure performance, club head velocity (CHV) and X-factor were used in the current study. In order to achieve a greater hitting distance, an increase in CHV is needed at impact (Joyce, Burnett, Cochrane, & Ball, 2013). Further, it has been shown that higher skilled golfers hit the ball farther when compared to lower skilled golfers (Hellström, 2009; Lindsay, Mantrop, & Vandervoort, 2008; Myers, Lephart, Tsai, Sell, Smoliga &

Jolly, 2008). CHV has been validated as an applicable surrogate for hitting distance in laboratory based studies (Fradkin, Sherman, & Finch, 2004)

The X-factor was also used in the current study as a performance variable due to the positive correlation found between it and CHV (Myers et al., 2008; Zheng, Barrentine, Fleisig, & Andrews, 2008). The X-factor has been defined as the difference of rotation between the trunk and the pelvis at the top of the backswing (Cheetham, Martin, Mottram, & St Laurent, 2001; Hellström, 2009; Myers et al., 2008). If the trunk rotates farther than the pelvis in the backswing (an increased X-factor), a stretch-shortening cycle is elicited in the trunk musculature (Hellström, 2009). When this happens, due to the summation of forces principle, increased segment velocities occur, which in turn increase the velocity of the golf club head (An et al., 2013; Cheetham et al., 2001; Hume, Keogh, & Reid, 2005).

Based on the principles of a stretch-shortening cycle and summation of forces, if participants' X-factor increases an increase in CHV should follow. Both CHV and an increased X-factor have been linked to an increased performance level (Fradkin et al., 2004; Myers et al., 2008; Zheng et al., 2008). Although the X-factor is just one of multiple variables that affect performance, it initiates the downswing and promotes proper proximal-to-distal sequencing of body segments (Ball & Best, 2007; Fujimoto-Kanatani, 1996). Since the golf club is the most distal segment, it will have the greatest velocity, which in turn will lead to an increase in performance (Chu, Sell, & Lephart, 2010).

The purpose of this study was to investigate the effect of external attentional focused instructions among recreational golfers and their performance over a lengthened training period and extended retention interval. Performance was measured by the X-factor and CHV. The current study extended the work of An et al. (2013). The training period of the current study was lengthened to four days, completing 50 trials per day. Retention tests were extended to 3, 6, and 10 days after the training period concluded. The methodological additions, such as an extended training period with spaced trial blocks were grounded in the practice scheduling and memory consolidation hypothesis literature (Arthur et al., 2010; Shea et al., 2000; Shewokis, 2003). It was hypothesized participants given an externally focused instruction would demonstrate greater X-factor and CHV during the training and retention interval compared to a control group (An et al., 2013; Arthur et al., 2010; McNevin, Shea, & Wulf 2003; Wulf et al., 2001; Shea et al., 2000; Shewokis, 2003). This is one of few studies (Arthur et al., 2010) to use a lengthened training period and extended retention interval on a complex discrete task like a full golf swing.

Methods

Local golfers and students from a Northwest university were recruited for this study. In order to participate, participants were required to meet specific inclusion criteria. Inclusion criteria for the current study was: being between the ages of 18 and 50 (the minimum age limit for the Professional Golf Associates Championship Tour), ability to attend the 7 data collection sessions, bring their own clubs, and play less than two rounds of golf per month. If prospective participants failed to meet any of those criterions, they were excluded from participation.

Task

The research study took place at a Northwest university's biomechanics laboratory. Participants were asked to hit golf balls off an octagon shaped astro-turf mat (1.47 m diameter) using a driver into a net. The net was located 3.2 m away from the edge of the mat. General instructions were provided to all participants ("act as if you are hitting the ball as far and as straight as possible").

Instrumentation

An 8 camera Vicon Nexus system (Vicon Motion Systems Ltd., United Kingdom) was used to capture CHV by a three retro-reflective marker cluster on the golf club head. The cameras capture rate was 120 Hz. CHV data were analyzed in Visual 3D analysis software (C-Motion Inc., Maryland, USA).

X-factor was captured by two inertial measurement unit sensors (IMU; InterSense, Massachusetts, USA) placed on the trunk and sacrum. A total of seven IMUs were attached to participants via Velcro belts except for the sensor on the trunk, which was placed in an elastic backpack. The additional sensors were placed on the head and bilaterally on the upper and lower arms allowing for a single model to accommodate both right and left handed golfers. The sampling rate for the IMUs was 180 Hz. Data collected from the IMUs were analyzed through MotionMonitor Toolbox (Illinois, USA).

Additionally, two in-ground force plates (Kistler, New York, USA) were used to collect ground reaction force data (2400 Hz) for an objective manipulation check for the externally focused (EF) group. Participants were standing with one foot on each plate.

Resultant peak ground reaction forces (GRF) of the lead leg were calculated for the pre-test and training period trials.

Experimental Protocol

Data collection for each participant took place on seven days over a three week period. Participants were encouraged not to practice golf in between training period days or in between retention days. All participants underwent a pre-test, a four day consecutive training period, and three delayed retention tests at days 3, 6, and 10 following the training period. All data collection days followed the same procedures; participants were outfitted with IMUs upon arrival, a warm-up that consisted of hitting golf balls off the mat until comfortable, then once comfortable participants were given general instructions of “act as if you are hitting the ball as far and as straight as you can.”

Following these instructions, participants were then provided an overview for the day (e.g., number of trials to be completed). Participants would then begin their training period (5 blocks of 10 trials each day) or retention tests (1 block of 10 trials).

The first day of the study included the pre-test (with no attentional focused instruction) followed by the first training period day. Attentional focus instructions were given to the EF group during the two minute rest break after the pre-test, and repeated after every trial. Since all EF participants were right handed the instruction was the same, “push against the left side of the ground as you hit the ball” (An et al., 2013); the control (C) group received no instruction. The EF group was asked, at the end of each trial, to give a percentage to which they adhered to the instruction. This was self-report manipulation check to determine if participants focused their attention appropriately (An et al., 2013). Resultant peak GRF generated by the lead foot were calculated by data collected from the force plates and served as an objective manipulation check. The externally focused cue intended to focus participants' attention to push with more force through their front foot.

Training days two through four followed a similar protocol to day one, with the exception of the pre-test. Each training day consisted of five trial blocks of 10 trials for 50 total trials each day. The EF group continued to receive the externally focused instruction after every trial through these three days. Participants continued to self-report their adherence rate and force plate manipulation checks were still collected. Three, six, and 10 days after the training period, participants underwent a retention test each of those days.

All three retention tests consisted of one block of 10 trials each. No attentional focus instructions were given during the retention tests, however, the general instruction of "act as if you are hitting the ball as far and as straight as you can" was still provided as a reminder. The retention tests followed the same protocol as the training period, participants would be outfitted with the IMUs and would warm-up until comfortable, and then data collection would begin.

Variables and Data Analysis

Data were reduced using methods similar to that of An et al. (2013). The number of trials used for analysis was reduced to the top five CHV speeds for the pre-test and retention tests for each participant. For the training period, trials were reduced to the top CHV per block per participant (five total trials per day) and were used for further analysis. CHV was determined as the peak velocity at the bottom of the downswing (Higdon, Finch, Leib, & Dugan, 2012). The X-factor was calculated for the corresponding trials. The following sections contain detailed information regarding 1) how manipulation check data were analyzed and reported; 2) methods used to filter, compute, and analyze CHV and X-factor data; and 3) the statistical test used to check for significance.

Dependent Variables. Prior to calculating CHV, data collected from the Vicon Nexus system were filtered with a bidirectional Butterworth filter with a cutoff frequency set at 6 Hz. Peak CHV was calculated for comparisons. CHV values from the training period and retention tests were compared to the five pre-test trials with the highest CHV values.

The X-factor value was calculated as the axial rotation of the trunk relative to the pelvis at the top of the backswing. Top of the backswing was determined as the highest position of the left wrist IMU, similar to An and colleagues (2013). The IMUs placed on the trunk and sacrum were used to measure the position of the trunk and pelvis, respectively. Although previous studies have used the address position (the time period prior to the start of the backswing) as a global zero, the current study allowed any trunk and/or pelvis rotation at the address position as it still affects the X-factor (Myers et al., 2008).

For the self-reported manipulation check, EF participants were asked to give a percentage to which they adhered to the externally focused instruction for all of the training period days, similar to An et al. (2013). Those percentages were then calculated as group means and standard deviations for each day of the training period.

For the second manipulation check involving force plates, data were filtered with a bidirectional, low-pass Butterworth filter with a cutoff frequency set at 25 Hz. Resultant peak GRF from each training period trial was compared to the average peak GRF of the pre-test trials. GRFs were normalized to participants' body weight. Training period force production was compared to the pre-test force production and represented as a percentage of the force produced from the pre-test.

Statistical Analysis. CHV and X-factor data were analyzed separately. Training period data for the X-factor and CHV were analyzed with 2 (Group; EF and C) × 4 (training period days) repeated measures ANCOVA. Retention data for both variables were analyzed with 2 (Group) × 3 (retention interval day) repeated measures ANCOVA. The pre-test data for X-factor and CHV were used as covariates for all corresponding analyses, which controlled for variance in performance level prior to receiving (EF group) or not receiving (C group) attention focus instructions.

Results

X-Factor

Repeated measures ANCOVA Training period testing day main effect, $F(1, 7) = 1.625$, $\eta^2 = 0.494$ and group main effect, $F(1, 7) = 1.646$, $\eta^2 = 0.19$ were not significant. Retention interval testing day main effect, $F(1, 7) = 0.917$, $\eta^2 = 0.234$ and group main effect, $F(1, 7) = 0.037$, η^2 0.005 were not significant. Mean values for X-factor measurements for the EF and C groups are presented in Figure A.1. Means and standard deviations are presented in Table A.1.

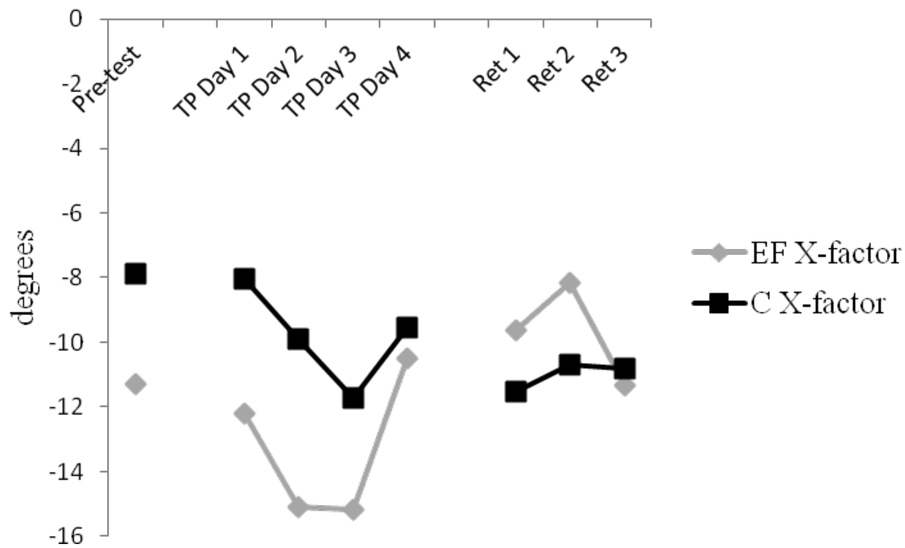

Figure A.1: Raw X-factor measurement data for the EF and C groups for pre-test, training period, and retention interval; negative number means greater X-factor

Table A.1:
X-factor Measurements for EF and C Groups

	X-factor	
	EF group	C group
	M(*SD*)	M(*SD*)
Pre-test	-11.295 (4.35)	-7.875 (6.55)
Training Period Day 1	-12.1875 (4.53)	-8.03 (5.45)
Training Period Day 2	-15.112 (5.44)	-9.894 (5.72)
Training Period Day 3	-15.166 (5.29)	-11.734 (7.55)
Training Period Day 4	-10.506 (3.13)	-9.527 (7.23)
Retention Day 1	-9.617 (5.90)	-11.536 (6.20)
Retention Day 2	-8.152 (5.06)	-10.700 (3.65)
Retention Day 3	-11.314 (4.12)	-10.794 (3.18)

Measurements are in degrees; negative means more rotation

CHV

CHV results are presented in Figure A.2. For the training period, main effects for training day ($F(1, 7) = 0.32$, $\eta^2 = 0.161$) and group ($F(1, 7) = 0.141$, $\eta^2 = 0.002$) were not significant; interactions were also not significant. For the retention interval, main effects for training day (F (1, 7) = 0.869, η^2 = 0.225) and group (F (1, 7) = 0.369, η^2 = 0.05). Means and standard deviations are presented in Table A.2.

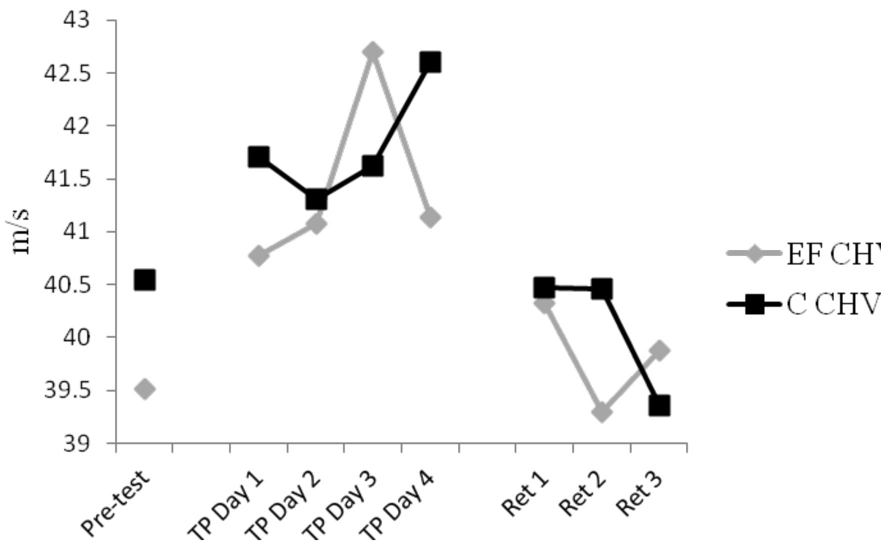

Figure A.2: Raw CHV for the EF and C groups for pre-test, training period (TP), and retention interval (Ret)

Table A.2:
Club Head Velocity Measurements for EF and C Groups

	CHV	
	EF group	C group
	M(*SD*)	M(*SD*)
Pre-test	39.518 (4.35)	40.544 (6.31)
Training Period Day 1	40.770 (4.53)	41.706 (6.08)
Training Period Day 2	41.081 (4.84)	41.308 (5.31)
Training Period Day 3	42.704 (2.53)	41.626 (5.33)
Training Period Day 4	41.140 (3.96)	42.599 (5.34)
Retention Day 1	40.330 (4.35)	40.476 (5.09)
Retention Day 2	39.296 (4.31)	40.455 (5.09)
Retention Day 3	39.881 (4.48)	39.361 (5.79)

Measurements in m/s

Manipulation Checks

Two manipulation checks were used to determine the EF groups' adherence to the externally focused instruction of "push against the left side of the ground as you hit the ball." The self-reported adherence percentages are presented in Table A.3.

Table A.3:
EF group self-reported manipulation check

	Training Period			
	Day 1	Day 2	Day 3	Day 4
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Percentage of adherence	83.65 (10.74)	86.70 (10.59)	85.15 (16.83)	83.69 (12.87)

Means and standard deviations of the force plate manipulation check are presented in Table A.4. The percentage values are the average force of a day compared to the pre-test force value of 1.29 Newtons (N) · body weight $(BW)^{-1}$. For example, the average force generated on training period day 1 was 1.34 N · BW^{-1}, which is 103.8% of the 1.29 N · BW^{-1} pre-test group average.

Table A.4:
Percentages of Force Generated by the Lead Foot

	Training Period			
	Day 1	Day 2	Day 3	Day 4
	M (*SD)*	*M* (*SD)*	*M* (*SD)*	*M* (*SD)*
Newtons · BW^{-1}	1.34 (0.37)	1.42 (0.44)	1.44 (0.56)	1.47 (0.45)
Percentage	103.8	110.3	112.0	113.9

Percentage is based on pre-test force production of 1.29 N · BW^{-1}

Missing Data

Two participants (one participant from each group) missed the third day of the training period, and another missed the final retention test. No participant missed more than one day. For all participants, the previous day's data was used to fill the missing data (Peugh & Enders, 2004). In addition, a separate repeated measures ANCOVA was conducted with means of the day prior and after the missed day to ensure the results were not different. Statistical results were not affected by using the previous day's data compared to the mean of the day prior and after the missed day. No significance was found with either method: for CHV with the previous day's data $p = 0.233$; for CHV with the day prior and after mean $p = 0.718$; for X-factor with the previous day's data $p = 0.152$; for X-factor with the day prior and after mean $p = 0.449$. A third participant, from the control group, missed the third retention test. Repeated measures ANCOVA was used with an average of the first and second day's data and with the second day's data filling the missing data for this particular participant. There was no statistical difference with either method (for CHV with the day prior and after mean $p = 0.640$; CHV with previous day's data $p = 0.688$; X-factor with the day prior and after mean $p = 0.141$; X-factor with previous day's data $p = 0.152$). Lastly, due to technical issues, another participant's (EF group) pre-test X-factor data was not useable. This participant's data were not used in any analysis since pre-test data were the covariate for all analyses.

Discussion

The purpose of this study was to investigate the effect of external attentional focus instructions among recreational golfers and their performance over a lengthened training period and retention interval. It was hypothesized the EF group would exhibit greater X-factor and CHV measurements during the training and retention interval compared to the C group (An et al., 2013; McNevin et al., 2003). The findings of the current study do not support the hypothesis. Both groups' X-factor and CHV results displayed trends of performance improvements through the first two days of the training period. However, at the third day of the training period, the EF groups' performance plateaued then decreased at the fourth day. The C group followed a similar trend to the EF group. These results are not consistent with previous studies, which concluded externally focused groups perform better than other groups (An et al., 2013; Arthur et al., 2010; Bell & Hardy, 2009; Chivacowsky et al., 2010; McNevin et al., 2003; Wulf, 2013; Wulf & Su, 2007).

The current study used a distributed practice schedule compared to An and colleagues (2013) who used a massed practice schedule. At the second training period day, participants in the current study completed the same number of trials as participants in the An and colleagues study. When comparing the first two days of the current study to An et al. (2013), the results would be similar in the EF group. Yet, when observing the third and fourth days of the current study, participants in the EF group did not perform as well as the previous days. This could have revealed a threshold of the amount of days or trials where instructions have a positive effect on performance. If a distributed practice schedule was used in collaboration with instructional techniques, the instruction may need to be changed over the practice schedule

There were differences between the current study and An et al. (2013). An and colleagues measured performance by carry distance (measured by a Flightscope), X-factor stretch, and angular velocities of the pelvis, shoulders, and wrists. However, the current study used CHV, which has been validated as an applicable surrogate for carry distance by Fradkin et al. (2004) and X-factor. The X-factor was used based on the wide usage in biomechanics (Myers et al., 2008; Zheng et al., 2008) literature compared to the X-factor stretch (Cheetham et al., 2001), which is used less. Angular velocities of body segments were not used because a greater X-factor increases the sequencing of body segments (Chu et al., 2010). It can be assumed these differences are negligible since a greater CHV is needed for a greater carry distance (Joyce et al., 2013) and an increased X-factor leads to proper sequencing of body segments (Chu et al., 2010).

Another potential reason for the current study not supporting previous research (An et al., 2013) was how the trunk was modeled. Typically the trunk is modeled where the acromion processes are used to identify the superior aspect of trunk position (An et al., 2013; Healy et al., 2011; Myers et al., 2008; Zheng et al., 2008). In the current study, the trunk was modeled by the IMU placed between the shoulder blades. This model differs from An et al. (2013) where the trunk was modeled as rotation of the shoulders (by the acromion processes) relative to the pelvis. The trunk model in the current study is the most appropriate model to measure trunk rotation of the X-factor since the acromion processes move at the top of the backswing due to shoulder blade protraction and retraction (Myers et al., 2008). The current model eliminated movement of the acromion processes. While using the acromion processes to model the trunk may display a greater X-factor measurement, it does not capture trunk rotation so much as it does acromion process movement. Trunk rotation, not shoulder rotation, elicits a stretch-shortening cycle, which leads to a greater force generated at the club head, thus increasing performance.

The C group also showed trends of performance improvement through the training period without receiving any instruction. In addition, the C group also increased the force produced by their lead leg over the training period. Even without an instruction prompting them to increase force production, the C group did so on their own. Due to this, the results of the current study may suggest that a distributed practice schedule may initially change performance, but using an external focus of attention may supplement performance changes from the practice schedule. As stated previously, the instruction may need to be changed throughout the practice schedule, otherwise a decrease in performance may be seen.

Limitations

As in every study, the current study had limitations, one being a small sample size. A power analysis revealed seven participants were needed for each group, for a total of 14 participants. Data from nine participants were analyzed, four from the EF group, and five from the C group. A small sample size may have affected the statistical results of the study. A second limitation was the golfing experience of participants in the current study. Collectively, participants had an average golfing experience of nearly 11 years, but with a standard deviation of 7 years. For the EF group, there was a range of 13 years of experience and for the C group there was a range of 24 years of experience. Having a wide range of participants gives merit to having a more homogenous sample population to reduce experience as a confounding variable.

Conclusion

The externally focused instruction used in this study intended to shift participants' focus to increase the amount of force generated by their lead foot. Future studies need to investigate whether timing of force production is more important than simply producing a greater force with the lead leg to increase performance in CHV and X-factor. The instruction for the current study was simply to push into the ground as participants hit the ball. Future studies should investigate if there is a more effective place throughout the swing to increase force production of the lead leg rather than when hitting the golf ball.

While no significant differences in performance were found between the EF or C groups, the current study does have practical implications. Potentially, regardless of the instruction given, participants may exhibit changes in performance with a distributed practice schedule. Then, using attentional focus instructions to augment the practice schedule may result in a quicker progression of performance change. As seen from the EF group however, the instruction given over the duration of the practice schedule may need to change. This is important in practical settings where practice may be distributed due to time constraints or other life priorities, yet performance may still be improved contrary to previous evidence, such as Lee and Genovese (1988, 1989). The results of this study support the need for further investigation within motor learning in regards to how discrete and continuous tasks are best practiced.

References

An, J., Wulf, G., & Kim, S. (2013). Increased carry distance and x-factor stretch in golf through an external focus of attention. *Journal of Motor Learning and Development*, *1*, 2-11.

Arthur, W., Day, E., Willado, A .J., Boatman, P. R., Kowollik, V., Bennett, W., & Bhupatkar, A. (2010). The effect of distributed practice on immediate posttraining, and long-term performance on a complex command-and-control simulation task. *Human Performance*, *23*(5), 428-445.

Ball, K. A., & Best, R. J. (2007). Different centre of pressure patterns within the golf stroke II: Group-based analysis. *Journal of Sports Sciences*, *25*(7), 771-779.

Bell, J. J., & Hardy, J. (2009). Effects of attentional focus on skilled performance in golf. *Journal of Applied Sport Psychology*, *21*(2), 163-177.

Cheetham, P. J., Martin, P. E., Mottram, R. E., & St Laurent, B. F. (2001). The importance of stretching the "X-Factor" in the downswing of golf: The "X-Factor Stretch". *Optimising performance in golf*, 192-199.

Chiviacowsky, S., Wulf, G., & Wally, R. (2010). An external focus of attention enhance balance learning in older adults. *Gait & Posture*, *32*(4), 572-575.

Chu, Y., Sell, T. C., & Lephart, S. M. (2010). The relationship between biomechanical variables and driving performance during the golf swing. *Journal of Sports Sciences*, *28*(11), 1251-1259.

Fradkin, A. J., Sherman, C. A., & Finch, C. F. (2004). How well does club head speed correlate with golf handicaps?. *Journal of Science & Medicine in Sport*, *7*(4), 465-472.

Fujimoto-Kanatani, K. K. (1996). *Determining the essential elements of golf swings used by elite golfers* (Unpublished doctoral dissertation). Oregon State University, Corvallis, Oregon.

Healy, A., Moran, K. A., Dickson, J., Hurley, C., Smeaton, A. F., O'Connor, N. E., & … Chockalingam, N. (2011). Analysis of the 5 iron golf swing when hitting for maximum distance. *Journal of Sports Sciences*, *29*(10), 1079-1088.

Hellström, J. (2009). Competitive elite golf. *Sports Medicine*, *39*(9), 723-741.

Higdon, N.R., Finch, W., Leib, D., & Dugan, E. L. (2012). Effects of fatigue on golf performance. *Sports Biomechanics*, *11*(2), 190-196.

Hume, P. A., Keogh, J., & Reid, D. (2005). The role of biomechanics in maximising distance and accuracy of golf shots. *Sports Medicine*, *35*(5), 429-449.

Joyce, C., Burnett, A., Cochrane, J., & Ball, K. (2013). Three-dimensional trunk kinematics in golf: between-club differences and relationships to clubhead speed. *Sports Biomechanics*, *12*(2), 108-120.

Lee, T. D., & Genovese, E. D. (1988). Distribution of practice in motor skill acquisition: Learning and performance effects reconsidered. *Research Quarterly for Exercise & Sport, 58*(4), 277-287.

Lee, T. D., & Genovese, E. D. (1989). Distribution of practice in motor skill acquisition: different effects for discrete and continuous tasks. / Repartition de la pratique dans l ‘acquisition de l ‘ habilete mortrice: differents effets pour des taches discontinues et continues. *Research Quarterly for Exercise & Sport, 60*(1), 59-65.

Lindsay, D. M., Mantrop, S., & Vandervoort, A. A. (2008). A review of biomechanical differences between golfers of varied skill levels. *International Journal of Sports Science &Coaching, 3*(0), 187-197.

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2011). Neuromuscular effects of shifting the focus of attention in a simple force production task. *Journal of Motor Behavior*, *43*(2), 173-184.

McNevin, N. H., Shea, C. H., & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research*, 67, 22-29.

Myers, J., Lephart, S., Tsai, Y., Sell, T., Smoliga, J., & Jolly, J. (2008). The role of upper torso and pelvis rotation in driving performance during the golf swing. *Journal of Sports Sciences*, *26*(2), 181-188.

Peugh, J. L., & Enders, C. K. (2004). Missing data in educational research: A review of reporting practices and suggestions for improvement. *Review of educational research*, *74*(4), 525-556.

Shea, C. H., Lai, Q. Q., Black, C. C., & Park, J. H. (2000). Spacing practice sessions across days benefits the learning of motor skills. *Human Movement Science, 19*(5), 737-760.

Shea, C H., & Wulf, G. (1999). Enhancing motor learning through external-focus instructions and feedback. *Human Movement Science*, *18*, 553-571.

Shewokis, P. A. (2003). Memory consolidation and contextual interference effects with computer games. *Perceptual & Motor Skills*, *97*(2), 581-589.

Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport & Exercise Psychology*, *6*(1), 77-104.

Wulf, G., Chiviacowsky, S., Schiller, E., & Ávila, L. T. G. (2010). Frequent external focus feedback enhances motor learning. *Frontiers in psychology*, (*1*), 190, 1-7.

Wulf, G., Höß, M., & Prinz, W. (1998). Instructions for motor learning: differential effects of internal versus external focus of attention. *Journal of Motor Behavior, 30*, 169-179.

Wulf, G. G., Lauterbach, B. B., & Toole, T. T. (1999). The learning advantages of an external focus of attention in golf. / Avantages, pour l'apprentissage du golf, d'une attention focalisee sur l'effet de l'action. *Research Quarterly For Exercise & Sport*, *70*(2), 120-126.

Wulf, G., McConnel, N., Gärtner, M., & Schwarz, A. (2002). Enhancing the learning of sport skills through external-focus feedback. *Journal of Motor Behavior*, *34*(2), 171-182.

Wulf, G., McNevin, N.H., & Shea, C.H. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *Quarterly Journal of Experimental Psychology 54A*, 1143-1154.

Wulf, G., & Su, J. (2007). An external focus of attention enhances golf shot accuracy in beginners and experts. *Research Quarterly For Exercise & Sport*, *78*(4), 384-389.

Zachry, T., Wulf, G., Mercer, J., & Bezodis, N. (2005). Increased movement accuracy and reduced EMG activity as the result of adopting an external focus of attention. *Brain Research Bulletin*, *67*(4), 304-309.

Zheng, N. N., Barrentine, S. W., Fleisig, G. S., & Andrews, J. R. (2008). Kinematic analysis of swing in pro and amateur golfers. *International Journal of Sports Medicine*, *29*(6), 487-493.