Examining visual and attentional focus influences on golf putting performance using a dual-task paradigm

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Abstract

Visually focusing on the hole versus the ball in golf has shown some positive effects on putting performance (Heath et al., 2008), yet the reason for these benefits have not been tested. Considering the benefits of adopting an external focus, the purpose here was to examine whether attentional focus mechanisms contribute to the positive effects reported by Heath et al. (2008). Thirty experienced golfers were assigned to either a visual-ball focus or visual-hole focus group. Following warm-up putts, 48 experimental putts, divided equally into 16 putts across three conditions: control, task-relevant, and task-irrelevant, were performed. In the control condition, participants putted under single-task conditions, maintaining their assigned visual focus. In the other two conditions, participants putted under dual-task conditions and were instructed to focus on their wrist angles upon hearing a tone (task-relevant), or to identify an irrelevant sound (task-irrelevant). A questionnaire, designed to represent equal proportions of the 'distance' effect (Wulf, 2013; i.e., internal, proximal external, or distal external focus), served as a manipulation check to determine the attentional focus adopted under each condition. Analysis of the manipulation check for the control condition data only showed a significant interaction of Group and Attentional Focus $F(2,56) = 4.5$, $p = .01$. Post-hoc showed that participants had a significantly higher proximal external focus in the visual-ball focus group compared to the visual-hole focus group, whereas the visual-hole focus group was significantly higher than the visual-ball focus group for distal external focus. Additionally, an analysis with all three putting conditions indicated that participants had significantly higher internal focus for task-relevant trials, as compared to task-irrelevant or control trials. There were no significant differences found for any of the putting performance measures., however, the main effect of Condition did approach significance for MRE $F(2,56) = 2.8$, $p = .068$. This replicates the general finding that putting performance is poorest when golfers self-report using a higher internal focus. In conclusion, these results suggest that visually focusing on the hole results in a more distal external attentional focus in a golf environment than that of a ball-focus, but this does not translate to performance benefits.

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Chapter 1: Introduction

Fourteen golf clubs are allowed in a bag during a golf competition scenario. The putter, as one of those 14, may well be the most crucial club as it is used for more shots than any of the other thirteen clubs in the bag. In 2015, the Professional Golf Association (PGA) showed 41% of all strokes made during tournament rounds were putts (PGA Tour, 2016a; PGA Tour, 2016b). Despite this importance, many golfers are resistant to deviating from their standard practice, which typically involves looking at the ball before they putt. According to Hogan (1948), more effort is spent trying new putters, adjusting grips, or modifying the stroke than actually trying to understand why we may not putt as effectively as we could (as cited in Aksamit & Husak, 1983). A recent suggested practice for improved putting is to visually focus on the hole instead of the ball (Heath, Alpenfels, & Christina, 2008).

Although visually looking at the hole while putting seems unnatural, it is not a completely new phenomenon in the golf world. Johnny Miller was one of the top golfers in the world in the 1970's, winning 25 PGA tour events (PGA Tour, 2017a). When Johnny found himself struggling on the greens, he decided to look at the hole instead of the ball. More recently, this putting technique has been used in NCAA tournament play, the European Tour, and the PGA Tour. Jordan Spieth and Louis Oosthuizen (ranked 5th and 27th in the Official World Golf Rankings as of January 27, 2016) (PGA Tour, 2017b) have also been seen using this technique in tournament play.

Only a small number of studies, however, have analyzed the visual focus of golfers, comparing one group who visually looks at the ball versus another group who looks at the hole. Of these few, most show that there is no significant difference between the two groups (Aksamit & Husak, 1983; Bowen, 1968; Cockerill, 1979; Gott & McGown, 1988). More recent analysis, however, has shown some positive effects to putting while looking at the hole (Heath et al., 2008; Mackenzie, Foley, & Adamczyk, 2011). The researchers of the two experiments which showed advantages for looking at the hole have forwarded some potential underlying mechanisms for the observed benefits. Of those mechanisms stated, the one of interest relates to the attentional focus adopted by golfers. It has been suggested that as golfers shift their visual focus to the hole, their attentional focus also shifts to a more *external* attentional focus. Heath et al., (2008, p. ix-x), for example, stated that this putting technique "requires that you focus both visually and mentally on the target – that you really cast your consciousness out to the place where you intend to leave the ball." Given the varied results of visually focusing on the hole versus the ball, I investigated whether a hole-focused putt leads to better putting performance in golfers, relative to looking at the ball. Further, considering the vast amount of literature supporting benefits to *external* versus *internal* attentional focus in motor performance, I also examined whether attentional focus mechanisms contributed to the possible benefits yielded by visually focusing on the hole instead of the ball. Specifically, I am interested to see whether the hole-focused putts lead golfers to adopt a more distal external focus, than that of the typical ball-focus, which is expected to generate more of a proximal external focus. This possible difference in a distal versus a proximal external focus is relevant as it has been shown that a distal external focus yields greater performance benefits than a proximal focus (Bell & Hardy, 2009; McKay & Wulf, 2012; McNevin, Shea, & Wulf, 2003; Porter, Anton, & Wu, 2012).

Given this research interest, in the literature review, I first describe in more detail the six experiments that have directly compared visually looking at the ball to visually looking at the hole. Benefits to adopting an external focus versus an internal focus will then be discussed, with a specific focus on experiments that used golf related tasks as examples. Once external focus benefits are understood, I will discuss the effectiveness of different external foci, supported by three categorical delineations – internal, proximal external, distal external – that relate to the ‘distance effect’ presented by Wulf (2013). Finally, I will provide background knowledge on the use of secondary tasks in experiments, and justify the use of a dual-task paradigm to examine possible contributions of attentional focus mechanisms. I will conclude with a description of my experimental design and my hypotheses.

Chapter 2: Review of Literature

Visual Focus Experiments in Golf

Golf is a very dynamic sport involving multiple components, leading to endless room for individual improvement. This may be why there is such a vast amount of research that uses golf tasks in their experimental designs. Practice scheduling (Porter, Landin, Hebert, & Baum, 2007) imagery techniques (Thomas & Fogarty, 1997), feedback mechanisms (Smith, Taylor, & Withers, 1997), gaze-behaviour (Vickers, 1999), and biomechanical aspects (Myers et al., 2008) are just a few examples of how golf has been researched over the years. Within these experiments, golfers adopt the traditional practice of looking at the ball prior to executing the golf shot. A small number of experiments, specifically six, however, have examined the influence of the visual focus prior to/and during a golf putt. Four experiments were conducted over the 20 years spanning 1968-1988 (Aksamit & Husak, 1983; Bowen, 1968; Cockerill, 1979; and Gott & McGown, 1988), and these were followed by two more recent experiments (Heath et al., 2008; Mackenzie et al., 2011). Each of these experiments are described in more detail next.

Bowen (1968) investigated 100 novice golfers (i.e., those defined as never having played or had limited experience with golf) who were divided into two groups: those who looked at the ball versus those who looked at the hole. Putts were performed without any practice on custom-made outdoor surfaces towards a standardized hole. Distance error and direction error were the dependant variables. Participants putted twenty-five times from three different distances (15, 25, and 35 feet) on four different terrains (level, uphill-sidehill, downhill-sidehill, and undulating) for a total of 300 putts. No significant differences were shown between the two groups, indicating that the visual hole-focused technique neither impaired nor improved putting skill for novice golfers.

Cockerill (1979) conducted similar experimentation, manipulating the visual focus of golfers during a putting task, but added the dimension of skill level. Forty right-handed participants were divided into two groups based on skill level – twenty “golfers” (handicaps 6 and below) and twenty “non-golfers”. Putts were performed without any practice, on a flat, synthetic putting surface towards a standardized hole, either 100 cm (3.28 ft.) or 200 cm (6.56 ft.) from the hole. Since putting distance was relatively short, vision was restricted using a triangular blinker made from a stiff card and attached to either the left side (ball-focused) or right side (hole-focused) of their head. Similar to Bowen (1968), no significant differences were found between the two putting techniques in either distance or direction errors, for either skill level.

Aksamit and Husak (1983) extended the visual-focus research further by adding an experimental group that was blindfolded. Twenty-seven female participants, who were all non-golfers, were divided into three groups evenly - visual ball-focus, visual hole-focus, or blindfolded prior to the putt. Five putts were performed without any practice from three distances (5, 10, and 15 ft.) on a real golf green. Absolute, constant, variable, and radial errors were computed and no significant difference was found between groups.

The last of the earlier visual-focus research was conducted by Gott and McGown (1988) who used a group of 16 non-golfers. In addition to two visual focus conditions (ball and hole), two different putting stances (normal and side-saddle) were also included. Each of the four combinations of visual-focus and stance were practiced for two weeks, followed by testing after each two-week period. During testing, sixty putts were performed from two distances (5 and 15 ft.) on an indoor-outdoor flat piece of carpet. Putts made, absolute error, and variable error scores revealed, once again, that there were no significant differences between any of the four conditions.

Of the two more recent experiments, Heath et al. (2008) reported on two studies conducted by Eric Alpenfels and Bob Christina, which manipulated the visual focus of participants. In 2002, the first study was performed to test the hypothesis that visually looking at the hole while putting is an effective *training* drill. Experienced golfers performed a pre-test while looking at the ball, from distances within the range of 23-43 feet. Following the pre-test, 40 putts while looking at the hole were performed from a different set of distances within the 20-40-foot range. Finally, a post-test was conducted with participants looking at the ball again, putting from the original locations used in the pre-test, ranging from 23-43 feet. Results showed that after practicing using the visual hole-focused technique, golfers reduced their average putting error by 9 inches.

Given these results, a second study by Alpenfels and Christina was conducted in 2005 (as cited in Heath et al., 2008). Similar to the earlier studies described (i.e., Aksamit & Husak 1983; Bowen, 1968; Cockerill, 1979; Gott & McGown, 1988), they wanted to directly compare the two visual focus groups. The experiment described was a four-phase design that used forty experienced golfers with handicaps ranging from 8-36. During the first phase, all 40 golfers putted to nine different holes, ranging in distance from 3-43 feet, in a random order. Participants were then divided evenly, balanced in terms of handicap and gender, and assigned to either the visual-ball focus group or the visual-hole focus group. During phase 2, golfers putted to the same nine holes as phase 1, also in a random order, this time maintaining their assigned visual-focus for each putt. Phase 3 of the experiment required each group to *practice* 45 putts from distances between 5-45 feet under their assigned visual focus. Finally, Phase 4 had the same requirements as Phase 2.

The average putting error in Phase 4 was measured, compared to their initial Phase 1 results, followed by a between groups comparison in Phase 4. Results showed that both groups showed improvements when comparing their Phase 1 average error score to their Phase 4 average error score, however, the visual-hole focus group improved "almost twice as much." More importantly, the between-group analysis during Phase 4 showed that on putts between 28-38 feet, the visual-hole focused participants putted the ball to an average distance of 28 inches from the hole, which was 9 inches closer than the visual ball-focused group who averaged 37 inches from the hole. Although results on shorter putts between 3-8 feet were not significantly different between groups, there was a trend that the hole-focused group performed better, averaging 3.5 inches closer than the ball-focused group. Relevant to the proposed research, results seen in Phase 2 showed an improvement of 5 inches for ball-focused and a decrement of 5 inches for hole-focused, compared to Phase 1 results. This implies that adopting a visual hole-focus may cause a decrease in performance initially, however, once 45 more practice putts were conducted, improvements were seen. Therefore, the proposed experiment will include the necessary amount of familiarization and practice trials before experimental trials begin.

More recently, Mackenzie et al. (2011) used 31 male golfers (handicap 18.7 ± 10.4) to investigate differences between a visual ball-focused group and a visual hole-focused group. This research was different from all the rest in that their interest was mostly related to the kinematics of the stroke. Participants completed a pre-test, then practiced using one of the two visual focus techniques, then a post-test using both techniques. Five putts were made on a synthetic putting surface from two distances – 1.22m and 4m (4 ft. and 13.12 ft.) – using both techniques, for a total of 20 putts per golfer. The four dependent kinematic variables related to putter were face angle, stroke path, impact spot, and putter speed. The number of successful putts was also monitored. There were no significant outcome differences between groups, however, results showed that practicing while visually focusing on the hole resulted in a statistically significant reduction in putter speed variability in comparison to practicing while visually focusing on the ball. This is a desirable component of the putting stroke because maintaining putter speed allows the golfer to more easily apply the proper force to the ball. Also, visually focusing on hole did not significantly affect the quality of impact as assessed by the variability in face angle, stroke path, and impact spot at moment of contact. Finally, the golfers' ability to start the ball on the intended target line was not affected by visually focusing on the hole.

Overall, of the six studies performed to date comparing visually focusing on the ball versus visually focusing on the hole during a golf-putting task, mixed results are seen. The differences in the methods used in each of the above-mentioned may provide some reasoning for the varied findings. Of the four studies that showed no effects, three used participants with no golfing experience, whereas both of the more recent studies used experienced golfers. The current experiment was interested in making recommendations relevant to the golf world; therefore, experienced golfers were used as participants.

Also important to note is that three of the four studies that displayed non-significant data did not give any practice or familiarization trials to the experimental group that had to look at the hole. As seen in research by Heath et al. (2008), the fact participants had to switch to an unfamiliar putting style had an immediate negative effect on performance. However, after only 45 practice putts while looking at the hole, this group out-performed the visual ball-focused group. Similarly, Mackenzie et al. (2011) had golfers perform 20 practice putts while looking at the hole and 20 while looking at the ball, eventually showing some visual hole-focused benefits.

Therefore, the inclusion of practice putts and familiarization trials is assumed to be important and has been used in the current research.

In terms of putt length, varying distances were used for the length of the putts in these studies, ranging from 1m (3.28 ft.) to 13.7m (45 ft.). Of the studies that used experienced golfers and modified the distance, putt length did not seem to have a large effect on performance. Consequently, during experimental trials, the current research exclusively used one putting distance.

It is interesting that all of the research done to date showed no performance decrement for having one's visual focus on the hole. More important, those researchers that obtained beneficial effects for looking at the hole, as compared to the ball, have speculated that such benefits may be related to an increased external focus of attention under such conditions (Heath et al., 2008; Mackenzie et al., 2011). No research to date, however, has examined whether this is a possible explanatory mechanism. Certainly, the learning and performance advantages of an external focus of attention over an internal focus is a very robust finding (see Wulf, 2013 for a review), and thus, this speculation is worthy of investigation.

Internal Versus External Focus of Attention

According to Magill (2003), attention can be defined as the engagement in the perceptual, cognitive, and motor activities associated with performing skills. In relation to sport, attentional focus has been a popular topic of interest and much research has been conducted relating to the attentional focus of athlete's practice and competition scenarios. While there have been different categorizations of attentional focus, that of most bearing to this research is the descriptions by Nideffer and Sagal (1998) and Wulf and Prinz (2001), which used direction to separate attentional focus into internal and external categories.

Numerous studies have manipulated the internal and external foci of their participants. According to Schmidt and Lee (2011), "internal" involves instructions to the participant to focus on some aspect of the motor skill, such as how a movement is being executed or the sensory consequences of the movement. For example, how the arms move or how wrist angles are maintained during a golf putt would be considered internal foci. More recently, Wulf (2013) clarified the definition of internal and external focus, stating that references to the performers *body* must be used in the internal focus instructions and that references to the movement *effect* must be used in external focus instructions. For an "external" focus of attention, Schmidt & Lee (2011) stated that instructions must direct the person to focus on an object in the environment or on some expected outcome of the action. An example of an external focus would be a golfer focusing on where the ball is supposed to go or the desired path of the ball during the putt (Schmidt & Lee, 2011).

Most research analyzing the direction of attentional focus in sport shows a benefit of external focus in activities such as basketball free throw (Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002; Zachry, Wulf, Mercer, & Bezodis, 2005), and darts (Lohse, Sherwood, & Healy, 2010; Marchant, Clough, & Crawshaw, 2007; McKay & Wulf, 2012), but more relevant are those specific to golf. For example, in golf pitching, Wulf, Lauterbach, and Toole, (1999) instructed one group to focus on the arm swing (internal) and another group to focus on the club swing (external). The external focus group out-performed the internal group in both practice and retention. Wulf and Su (2007) expanded on this research by adding a control group, and using both novice and expert golfers. The same instructions were given to participants and results again showed performance was better in the external focus groups. External focus benefits have also been seen in golf putting tasks. Granados (2010), for example, constructed multiple instructions for both internal and external focus conditions and showed that those participants who were instructed to have an external focus performed better than those who did not.

To explain the advantages associated with an external focus, Wulf, McNevin, and Shea, (2001) constructed the Constrained Action Hypothesis in which an internal attentional focus is thought to induce conscious control of the movement, which is argued to be less effective than automatic control mechanisms for movement. In contrast, when performers use an external attentional focus, it is hypothesized that this allows the motor system to engage in a more automatic control process and to rely on its self-organizational properties (Wulf et al., 2001; see Wulf & Lewthwaite, 2010 for an extension). It is clear that an external focus of attention can enhance the performance of individuals, based on the vast amount of literature showing these benefits. Therefore, it is feasible to state that a possible explanatory mechanism for benefits seen when visually looking at the hole is the adoption of a more external attentional focus. As such, in the current experiment, the attentional focus of golfers who adopt either a visual hole-focus or ball-focus was manipulated with the purpose of examining the possible contributions of attentional focus on golf putting performance under these conditions.

In her recent review, Wulf (2013) highlighted that attentional focus could be distinct from visual focus. That is, although a person may be visually focusing on one feature in the environment, his/her focus of concentration could be on a different feature. For example, a person throwing darts may be looking at the bull's-eye of the dartboard, but have their focus of attention on the action of the fingers releasing the dart, as opposed to the more optimal external focus of attention on the dart hitting the bull's-eye. More specific to the task of interest in the current experiment, it was recognized that focusing on the ball, similar to focusing on the hole, was still a form of external focus (Wulf, 2013). Within external foci, however, there are a range of categories with varying associated benefits. That is, an external focus of attention that is more distal generates greater benefits than one that is more proximal (Bell & Hardy, 2009; Kearney, 2014). These research outcomes has been referred to as the ‘distance effect’(Wulf, 2013) and is elaborated upon next.

The ‘Distance’ Effect

While the benefits of external attentional focus compared to an internal attentional focus have been shown, the effectiveness of different external foci has also been shown to be important (e.g., Bell & Hardy, 2009; McKay & Wulf, 2012; McNevin, et al., 2003; Porter et al., 2012). McNevin et al. (2003), for example, used a stabilometer task to compare one internal focus condition and three external focus conditions of varying marker locations. Results showed that when focusing on the two furthest – or more *distal* – markers, performance was enhanced relative to the more proximal marker locations. It was also reported that when participants focused on their feet in the internal focus condition, they had significantly larger error than the external focus of attention conditions.

Bell and Hardy (2009) used a similar experimental design as McNevin et al. (2003), adding an anxiety condition and using a golf pitch shot as the task. Regardless of anxiety, results showed that performance under conditions in which the participants focused on ball trajectory and landing point (distal external) was significantly more accurate than when they focused on the club (proximal external), which were better than those that adopted an internal focus (focus on wrist hinge and motion of arms). McKay and Wulf (2012) showed comparable results in dart throwing, with the distal external group (focusing on the bullseye) – performing significantly better than the proximal external group that focused on the flight of the dart. Finally, Porter et al.

(2012) showed similar results in a jumping task. Participants that focused on jumping towards a distal target performed better than those who focused on jumping further away from a proximal target. Overall, Wulf (2013) defines these findings as the 'distance' effect, where the greater benefits to performance (or learning) are seen under conditions in which the participant has used a distal focus as opposed to a more proximal or internal focus.

Specific to golf putting, Kearney (2014) also showed benefits to a more distal external focus. This task required participants to putt a golf ball towards a series of concentric circles on an indoor putting surface, attempting to try and stop the ball in the middle circle. In that research, internal focus was defined as thinking about the specific body movements necessary to leave the ball on the target, such as the distance the arms moved or the smoothness of the swing in relation to the shoulders. The proximal external focus related to the golf club and was defined as thinking about what one needed the club to do to leave the ball on the target, such as the club head movement. The distal external related to the path of the ball and holding an image of that desired outcome as the putt was executed. The outcome was that the performance was significantly better in the distal external focus condition than both the proximal external or internal condition, which did not differ from each other.

The findings from these experiments prompted the supposition for the current research: that the location of visual focus would lead a golfer to have a similar attentional focus. Thus, the logic is that a visual focus on the target (i.e., the hole) will naturally allow golfers to adjust their attentional focus to that of a distal external focus. In contrast, a golfer looking at the ball would adopt a proximal external focus. This more proximal focus would lead to a lesser advantage gained in golf putting than that of a distal focus. If benefits to visually looking at the hole are in fact related to a more optimal distal external focus, a task that induces an internal focus should then disrupt the performance of the visually hole-focused group more so than that of the visually ball-focused group. Based on this rationale, it is possible that the potential contributions of attentional focus can be examined via the use of a dual-task paradigm.

Dual-task Paradigm

In a dual-task paradigm, an individual performs a primary task in conjunction with a secondary task (Goh, Gordon, Sullivan, & Winstein, 2014), which can be discrete or continuous. In relation to the current experiment, the primary task was to putt the ball as accurately as possible. A discrete secondary task was used which required the golfers to respond to a specific audio tone after they completed their putting motion. In the past, secondary tasks such as these have been used for golf putting (Beilock, Carr, MacMahon, & Starkes, 2002; Beilock & Gray, 2012; Fisher & Etnier, 2014). Task-relevant secondary tasks have been used to force the golfer to consciously think about something related to their bodily movement during the putting stroke (i.e., to have an internal focus) (Mullen & Hardy, 2000), or to focus on a component of the skill execution (skill-focused task; Beilock et al., 2002; Beilock & Gray, 2012). Task-irrelevant secondary tasks, however, have the participant engage in a secondary task, but are unrelated to the required bodily movement or the task itself.

Beilock and Gray (2012) recently examined the impact of relevant and irrelevant secondary tasks during a golf putt. Of most importance was the first experiment in which they analyzed putting kinematics and putting accuracy of both novice (no golf experience) and expert golfers (handicap <10). The attentional control of participants was manipulated using two secondary tasks: (1) a task-irrelevant condition in which participants judged whether an auditory cue was a high (500Hz) or low (250Hz) frequency and, (2) a task-relevant condition in which participants judged the timing of an auditory cue relative to their putting stroke. It was assumed that the task-relevant condition would have the participants adopt an internal focus of attention during the golf stroke because they would have to direct their attention to the execution of the swing. The performance of the “expert” golfers is of most relevant to the current research. For this group of golfers, putting performance was less accurate in the task-relevant condition compared to the task-irrelevant condition. Therefore, it was concluded that forcing conscious control of the putting stroke had a significant detrimental effect on experienced golfers; a finding in line with Wulf et al.’s (2001) constrained action hypothesis. In relation to the timing of the tone, the earlier the tone was presented in the putting stroke, the more detrimental the effects were on golfers regardless of skill level (see Fisher & Etnier, 2014, for similar results).

The findings of Beilock and Gray (2012) influenced our choice of the secondary task techniques and the timing in which it would occur during the execution of the golf putt Specifically, a similar secondary task, in which a tone sounded and the golfer was asked to attend to a component of the golf swing relevant to its execution, was used for the internal focus condition. A modification to the instructions was made, however, because Beilock and Gray (2012) instructions did not specify a body part and Wulf (2013) has argued that an internal focus of attention must be induced with instructions related to bodily control. As such, I informed the participants about the importance of the wrist-angles during the putting stroke and directed their attention to that bodily aspect during the backswing of the putting stroke when the tone was heard. It was anticipated that this would induce an internal focus during the timing of the stroke in which it is expected to have its most impact.

Noteworthy is that this internal focus manipulation was induced by a tone, and the simple introduction of a tone could have impacted golf performance. Consequently, to eliminate a potential confound of the introduction of an auditory stimulus during the golf putt, a task-irrelevant secondary task condition was introduced. This task-irrelevant condition then acted as a control for the fact that the task-relevant condition required the participants to engage in two tasks at the same time and served to isolate the contributions of the internal focus from that of engaging in two tasks concurrently.

Design and Hypotheses

In the experiment, golfers with experience were divided into two groups: (1) Visual ball-focus and, (2) Visual hole-focus. Golfers took part in a series of putts under three conditions in total, one of which was a *control condition,* and two different dual-task conditions: (a) a *task relevant condition* in which participants later responded to an auditory cue with a body-related task and, (b) a *task irrelevant condition* in which participants later responded to an audio cue with an unrelated task. Both cues were presented during the backswing of the golfers' putting stroke.

Of the six studies that have compared visually looking at the ball versus visually looking at the hole, four showed non-significant results (Aksamit & Husak, 1983; Bowen, 1968; Cockerill, 1979; and Gott & McGown, 1988) and two showed certain benefits to looking at the hole (Heath et al., 2008; Mackenzie et al., 2011). Thus, there is still a research 'gap' in terms of which visual focus condition is optimal for golf putting. Therefore, the first research question was: *Does one's visual focus on the hole versus the ball influence putting performance?* Based on research that has shown the distance effect, the hypothesis was that a visual focus on the hole, that is more distal, would be better than that of the proximal external ball focus.

Assuming the first research hypothesis is confirmed, no previous literature has investigated potential mechanisms for these beneficial effects. There is a vast amount of external focus benefits in motor performance literature for various tasks, including aiming tasks.

Therefore, our second research question was: *Do attentional focus mechanisms contribute to the potential benefits of visually looking at the hole?* The hypothesis was that the visual focus on the hole would enable a distal external focus of attention under 'natural' conditions and thus contribute to performance benefits. Thus, when participants were induced to adopt an internal focus of attention via the secondary task, there would be a greater deterioration in performance for those in the hole-focused group, as opposed to those in the ball-focused group, who were assumed to adopt a proximal external focus. A manipulation check was conducted to confirm these two assumptions presented; (1) that visually focusing on the hole induces a distal external focus whereas a visual-ball focus would lead to a more proximal external focus, and (2) that the task relevant condition would induce an internal focus.

Chapter 3: Method

Experimental Design

A mixed-factor design was used for this experiment with one between factor and one within factor. The between factor was the assigned visual focus: (a) Visual ball-focus and (b) Visual hole-focus. Given the importance of both groups being similar on a number of features, a group assignment phase was conducted following an experimental session which gathered baseline data from the golfers. The within factor was the conditions under which each of the 48 trials were divided; specifically, 16 control (C) condition trials, 16 task-relevant (TR) trials, and 16 task-irrelevant (TI) trials. In the control condition, participants simply executed the putt under a single-task condition, maintaining their assigned visual focus. In the dual-task conditions, the participants executed the putt under their visual focus assignment while also completing a cognitive task upon hearing an auditory tone. In the task-relevant conditions, a tone sounded during the backswing of the putting stroke. It was at this time that the participants were instructed to focus on their wrist-angles because this is involved in the bodily control of the putt. In the task-irrelevant condition, similar to the task-relevant condition, an auditory stimulus was played during the backswing of the putting stroke and participants had to later identify the stimulus as one of three potential sounds (more details on this in procedures section).

Participants

To determine the appropriate number of participants, a power analysis was conducted using GPower 3.1 (Erdfelder, Faul, & Buchner, 1996) which revealed that 28 participants would adequately power the study at the 0.80 level. The number of participants was rounded up to 30 to allow for a counterbalancing procedure. Thirty (29 male, 1 female) participants between the ages of 18 and 77 (*M* age = 42.07, *SD* = 17.3) were recruited from Black Bear Ridge Golf Course in Belleville, Ontario. Golfers had at least 5 years of golf experience (*M* years = 24.2, *SD* = 14.1) and each had a registered handicap/index with Golf Canada (*M* handicap = 6.41, *SD* = 5.6). All golfers had exclusively used the traditional putting method in the past, which is characterized by visually looking at the ball as they putt. All participants were naïve to the aims of the experiment. The experimental design received approval by the Research Ethics Board at the University of Ottawa (see Appendix A).

Golf Environment

Data collection occurred in the natural environment on a practice green at a golf facility; therefore, I had to work within the constraints of this environment. The putting green was nominally flat. The use of a standardized hole was used in the group assignment phase and experimental trials to maintain the ecological validity of the study.

Materials

Equipment. The required equipment was set up on the putting green at the designated site. Markers and numbered signs were used to mark the locations from which participants must putt. All golfers used their own putter, but Titleist Pro V1 balls were provided. Twelve dark green ball markers numbered 1-12 were used to track the golf putts after each trial. A 3-foot by 4-foot custom-made measuring device was used to measure missed putts. A meter stick and right-angle ruler were also used as measurement devices. A Sony video camera was mounted on a tripod and used to heighten the participants' bodily awareness of the wrists (more details on this in procedures section). Auditory stimuli were administered using a Toshiba laptop and speakers. A display board with pictures of wrist angles (Appendices B1 and B2) or of images representing the auditory stimuli (Appendix C) was created for participants to use following their dual-task trials. A clipboard and desk was set up adjacent to the experimental section to enable participants to respond to questionnaires and forms.

Questionnaire and forms. Each participant completed a demographic questionnaire to gather information about the golfers' skill level, years of experience, golf practice frequency, golf playing frequency, how they traditionally putt the golf ball, and other general information (see Appendix D). Following pre-testing, each golfer responded using a Likert Scale concerning how comfortable they would be trying a new putting method which differed from their typical putting technique. The participants' response was referred to as the "Putting Technique Response" (see Appendix E). Three data collection sheets were created before Session 2 (see Appendices F1, F2, and F3).

The degree to which participants adhere to instructions should not be assumed during experimentation. According to Kearney (2014), internal and external attentional focus investigations are strengthened by the inclusion of repeated manipulation checks. Masters and Ogles, (1998) have specifically suggested that Likert-type checks during the activity are recommended when working with the manipulation of attentional foci. Therefore, during certain experimental trials, as a manipulation check, every participant responded to questions about their attentional focus using a Likert scale (see Appendix G). Each question asked, "To what extent were you focused on" with varying levels of external (i.e., distal external or proximal external) and internal (e.g., your wrist angle) focus statements. These nine questions were designed to represent equal proportions of the distance effect as distinguished by the three attentional focus categories of internal focus, proximal external focus, and distal external focus (Bell & Hardy, 2009; Kearney, 2014; McKay & Wulf, 2012). Thus, questions were divided equally among these categories with questions 1-3 relating to a distal external focus, questions 4-6 to a proximal external focus, and questions 7-9 related most to an internal focus.

The attentional focus manipulation responses were used in two ways. First, they were used to determine the assumptions concerning the visual focus factor; i.e., that the visual-hole focus would result in the adoption a greater distal external focus, as compared to a proximal external or internal focus, and the visual-ball focus would have a greater proximal external focus than both the distal external or internal focus categories. Second, they were also used to determine whether the task-relevant condition was operating as desired; with the expectation that higher internal scores would occur under this condition compared to the task-irrelevant and control conditions.

Procedure

The managers at Black Bear Ridge Golf Course were contacted and informed about the experimental procedures. They gave their permission for the practice green to be closed to the public during the experiment. Recruitment occurred through word-of-mouth and individual golfers were responsible for reading and signing their own consent forms.

Prior to the first session, participants were instructed to dress appropriately for golf putting, to wear the golf shoes that they would typically wear golfing, and to bring their putter of choice to be used during data collection. Using their own putter ensured that it was the proper length and allowed each golfer to feel comfortable and familiar with the club in their hands.

Figure 1 provides a visual overview of the experimental procedures. The sessions were conducted approximately two weeks apart from each other.

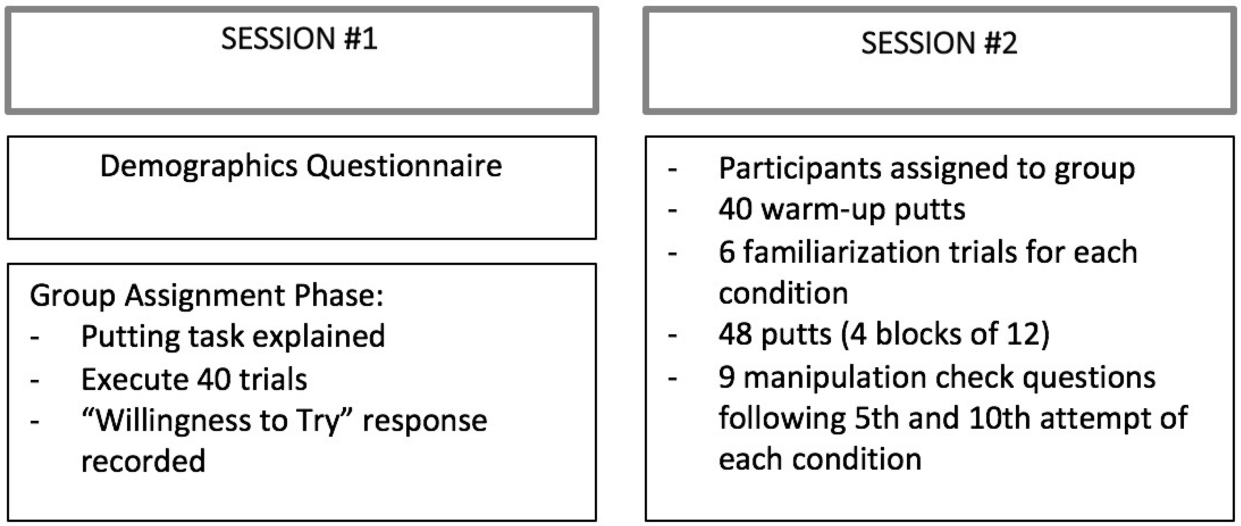

Figure 1. Visual overview of the experimental procedures for Session 1 and Session 2.

Session 1. The primary goal of the first session was to gather data to pseudo-randomly assign participants to their respective group such that they were as equal as possible on a number of levels. To this end, participants began by completing the demographic questionnaire. Next, the golfers performed 40 putts; 20 from an 8-foot (2.44 m) marker and 20 from a 12-foot (3.66 m) marker; both distances were different from the distance to be used in the second experimental session. Golfers all had a visual ball-focus during these putting strokes and they were informed to putt using the same technique as they used on a daily basis. Both putting distances were on a relatively flat surface. Putting location occurred in a pseudo-random order such that each distance was represented five times in a block of 10 trials. Missed putts were marked with a numbered ball marker once they had stopped rolling and were measured manually with a custom-made measuring device before moving on to the next 10-putt block.

Once the 40 trials were complete, the participant was asked, "To what extent would you be willing to try a new putting technique, which differs from the traditional method you currently use?" Participants circled a response on a Likert Scale ranging from 1 (not at all) to 5 (very much so) (Appendix E).

Previous studies that used a golf-putting task have taken the golfers handicap as a measure of putting ability. The handicap system is a general measure of playing ability, not a measure of putting ability. By using the putting scores attained by each of the participants in our "Group assignment phase" to determine putting ability, it gave us a more representative display of the participants' putting skill level. In addition to the putting results for group assignment, other data was used to match the groups as closely as possible for factors such as willingness to try the new technique, handicap, and years of experience. To do this, after trials were completed, each participant received a putting score, determined by calculating their mean radial error (MRE). Made putts were recorded in two dimensions as (0, 0). Golfers were then ranked in nominal order from the least amount of error to the most amount of error. Following this nominal ranking, the data from the demographic information, as well as the willingness to try a new putting technique, was used to match the two visual focus groups as much as possible. Lastly, three data collection sheets were created before Session 2 to ensure the randomization of trials amongst the conditions (see Appendices E1, E2, E3 for examples).

Session 2. In the second session, the participants were notified as to which visual-focus group they were assigned. Once given this information, the golfer performed 40 warm-up putts from various distances on the putting green - excluding the 10 ft. experimental distance - using their assigned visual-focus. Participants then received six familiarization trials for each of the three conditions.

Before the experimental trials began, participants were reminded of the primary task; to putt the ball as accurately as possible towards a standardized hole with a 10.8 cm diameter, attempting to make the putt. The participant placed the ball on the same marked location each trial, 10 feet (3.05 m) from the front of the hole. Putts were executed in a quasi-random order within each 12-trial block such that four of each trial condition (C, TR, TI) was executed per block. Once the ball came to a complete stop on missed putts, the experimenter used a numbered ball marker to replace the ball's location. Following each 12 trial-block of putts, the 12 ball locations were recorded and the ball markers were removed. The golfer had a small rest during this measurement interval.

One auditory tone and one of three unique auditory stimuli were heard in the task-relevant and task-irrelevant conditions, respectively. The auditory tone and stimuli were administered manually using a laptop and speakers adjacent to where the participant was putting. The video camera was mounted on a tripod and set up during Session 2, but only as a "duping" effect for the task-relevant condition (more detail provided in the task-relevant condition). The video camera was used during experimentation because it was thought it would increase attention to skill processes, particularly when one is told that one's performance would be evaluated in some manner (DeCaro, Thomas, Albert, & Beilock, 2011). Each of the conditions unfolded in the following manner:

Control condition. Prior to control trials, the experimenter said "normal putt" to notify the golfer that they were to putt under the single-task condition. The experimenter allowed the participant to partake in their typical pre-putt routine. Once they had addressed the ball and were visually fixated on the proper target, the golfer putted the ball as they naturally would on the golf course, maintaining the visual focus they were assigned.

Task-relevant condition. In this condition, participants were under the impression that they were being video-recorded and that their wrist angles would be measured following the data collection session. They were also informed prior to the experimental trials that maintaining the proper wrist angle is a fundamental technique used during a putting stroke and maintaining "firm wrists" is considered to be a key component of successful golf putting (Pelz, 2000). For each of these trials, the experimenter said "wrist-angle putt" to notify the golfer that he/she were to perform the putt under a dual-task condition in which the secondary task was to think about their wrist-angle at the sound of the tone. The experimenter allowed the participant to partake in their typical pre-putt routine. Once they had addressed the ball and were visually fixated on the proper target, the golfer putted the ball as they naturally would on the golf course, maintaining the visual focus they were assigned. Based on findings by Beilock and Gray (2012) and Fisher and Etnier (2014), the experimenter administered the 500Hz tone sometime between initiation of the backstroke and initiation of the downswing, with the tone having a duration of 0.4 ms. Participants were then presented the display board which had three different numbered images of varying golfers' wrist angles on a putter grip. The participants were prompted to select the image, verbally stating the number, which best represented their wrist angles when the sound of the tone had been heard during the previous putt. The images were designed to represent the grip style used by that particular participant: i.e., if the golfer gripped their putter with their right hand below their left hand, the images would replicate this (Appendix B1). No feedback on the wrist angle was given.

Task-irrelevant condition. For these task-irrelevant trials, the experimenter said "tone putt" to notify the golfer that he/she were to perform the putt under a dual-task condition in which the secondary task was to attend to a unique auditory stimulus played during that putt, with the intention to later identify the sound heard. The experimenter allowed the participant to partake in their typical pre-putt routine. Once they had addressed the ball and were visually fixated on the proper target, the golfer putted the ball as they naturally would on the golf course, maintaining the visual focus they were assigned. The experimenter administered one of three potential auditory stimuli; (1) telephone ring, (2) police siren, (3) air horn. These auditory stimuli occurred at a time interval between initiation of the backstroke and initiation of the downswing, with the stimuli having a duration of 0.4 ms. Participants were then presented a display board which had three different numbered images corresponding to the three potential sounds (see Appendix C) The participant had to verbally select which number best represented the auditory stimuli that was played during the previous putt. No feedback on their selection was given.

Manipulation check. Six manipulation checks were performed throughout to investigate the focus of attention that participants were adopting during the putting strokes. These manipulation checks occurred following the 5th and 10th attempt of each of the three conditions – C, TR, TI. The manipulation check involved the participants reading nine questions and responding by circling a number on a Likert scale that best represented their perceived attentional focus. I did not want the participants' initial exposure to the question-set to follow the same order for each participant as this could potentially affect how participants responded (i.e., if participants were always initially exposed to the questionnaire after task-relevant trials, they may base future responses relative to their task-relevant responses). Therefore, question-set exposure was counterbalanced. This resulted in one third of participants being initially exposed to the questions following a control condition, one third initially exposed following a task-relevant condition, and the final third initially exposed following a task-irrelevant condition. (See Appendices F1, F2, and F3).

Dependent measures

The nine-question attentional focus manipulation check used a Likert-type questionnaire to obtain average scores. Numeric response values from the nine questions were totalled for each *distance category* and corresponding *condition*. For example, the six total "proximal external" responses under the task-relevant putts were averaged into one score. The same was done for each of the distance category-condition combinations, for each participant.

There are various ways to compute accuracy scores for a given participant that is attempting a series of trials of a discrete task (Schmidt & Lee, 2013). Given that a putting task is a two-dimensional (2-D) task, it is important that our measurements reflect this. In previous literature, many target-oriented tasks were measured using a point system consisting of circular bands surrounding the target. According to Fischman (2015), no isomorphic relationship between the participant's score and the actual performance is created with this type of measurement system. It is also important to note that variability cannot be measured using a point system, since the exact location of each attempt is not precisely measured. Therefore, missed putts were measured as coordinates (x, y) and made putts were recorded as (0, 0). Measurements were made from the center of the golf hole and were measured using a home-made measuring device. This device was a stencil-like grid measured by the quarter-inch. Measurements were later converted to centimeters. The dependent measures for physical performance in my experiment were mean radial error (MRE), bivariate variable error (BVE), and putts made. MRE and BVE represent two distinct aspects of performance – accuracy (MRE) and consistency (BVE) – in two-dimensions (Hancock, Butler, & Fischman, 1995). Similar to Land et al. (2014), MRE was calculated as the average distance of each missed putt from the center of the hole and BVE was calculated as the square root of the *k* putts' mean squared distance from the centroid. The "centroid" represents the average ‘x’ and ‘y’ values of the missed putts, from one participant (Hancock et al., 1995). The MRE equation is displayed as Equation 1 and the BVE equation is displayed as Equation 2 (Note: *m* equals shots).

$$MRE = \overline{RE} = \left(\frac{1}{m}\right) \sum_{i=1}^{m} (RE_i) \quad (1)$$

$$BVE = \left\{\left(\frac{1}{k}\right) \sum_{i=1}^{k} [(x_i - x_C)^2 + (y_i - y_C)^2]\right\}^{\frac{1}{2}} \quad (2)$$

The first independent variable in this experimental design was the Group to which participants were assigned, varying by whether the participant was looking at the ball in the visual-ball focus group or looking at the hole in the visual-hole focus group. The second independent variable was the Condition under which participants were to putt (i.e., control/task relevant/ task irrelevant). The physical performance dependent variables included two measures of error, mean radial error (MRE) and bivariate variable error (BVE), as well as the successful putts made. Finally, attentional focus was measured by the manipulation check questionnaire, with each subscale yielding a potential score from 1-5. All data are expressed as means with standard error, and *F* values are provided for the main effects. Partial eta squared (η_p^2) is reported to provide an estimate of the proportion of the variance that can be attributed to the independent variable. Statistical significance was set at $p < .05$. When necessary, post-hoc analyses were performed to ascertain the location of significance.

Putting Performance.

Prior to data analyses, all data were first screened for individual outliers using standardized z-score values. While two participants did have outlier scores, these outliers made up less than 20% of their data. Therefore, all participants, and all their putting trials, remained in the data analysis. Skewness and kurtosis values were marginally greater than the acceptable value for some of the dependant variable scores, therefore, MRE and BVE values were transformed using the square-root function in SPSS to allow for a more normally-distributed data set. Levene’s Test indicated that the variances of error were equal for each dependant variable, therefore, homogeneity of variance could be assumed.

Chapter 4: Results

Group Assignment

Following Session 1, several factors were considered, with the goal of controlling for possible confounds, to assign participants to one of the two experimental groups: (1) Visual-ball focus group, or (2) Visual-hole focus group. T-tests were thus performed on those factors (i.e., putting error, age, handicap, years of experience, willingness to try new putting technique) to ensure that the groups were not different from each other on those variables. No significant differences between groups were found, all *p*-values > .05. The relevant descriptive statistics are presented in Table 1.

Table 1

Factors Considered for Group Assignment

	Group	
	Visual-Ball Focus	Visual-Hole Focus
Factor	*M(SD)*	*M(SD)*
Putting Error	7.67 (2.96)	7.74 (3.03)
Age	45.00 (17.60)	39.13 (16.91)
Handicap	6.75 (7.06)	6.06 (4.11)
Years of Experience	24.33 (13.76)	24.07 (14.45)
Willingness to Try	4.13 (1.12)	4.27 (1.03)

Note: *M = mean. SD = standard deviation. Willingness to Try* – Refer to Appendix E.

Manipulation Check

For the manipulation check data, a 2 Group (visual-ball focus, visual-hole focus) x 3 Condition (control, task-irrelevant, task-relevant) x 3 Attentional Focus Subscale (distal external, proximal external, internal) mixed-factor ANOVA was performed. This analysis showed a significant main effect of Condition $F(2,56) = 10.16$, $p = <.001$, $\eta_{p^2} =.266$. The task-relevant condition ($M = 3.55$, $SE = 0.12$) drew the greatest response average on the Likert scale questionnaire, with the control condition ($M = 3.36$, $SE = 0.11$) and task-irrelevant condition ($M = 3.12$, $SE = 0.11$) drawing less of a response, respectively. This main effect, however, was superseded by a significant two-way interaction between Condition and Attentional Focus Subscale $F(4,112) = 9.77$, $p = <.001$, $\eta_{p^2} =.259$. Fischer's LSD post-hoc testing indicated that during the task-relevant putting condition, participants focused significantly more on internal factors compared to the task-irrelevant and control conditions, which were not significantly different from each other. In addition, there was a greater distal external focus under the control condition as compared to the task-irrelevant condition, but the control condition was not different than the task-relevant condition. There were no differences amongst the means for proximal external focus across the three conditions (Refer to Table 2).

Table 2

Attentional Focus of Participants in Each Condition

	Condition		
	Control	Task-irrelevant	Task-relevant
Attentional Focus	*M(SE)*	*M(SE)*	*M(SE)*
Distal External	3.57 (0.18)	3.83 (0.25)	3.31 (0.21)
Proximal External	3.38 (0.16)	3.01 (0.23)	3.44 (0.17)
Internal	3.13 (0.20)	2.77 (0.28)	3.89 (0.16)

Note: For all scales, higher scores are indicative of more attention in this sub-category Comparison of interest is in boldface. *M = mean. SE = standard error.*

To test the assumption that a visual-hole focus in fact leads golfers to adopt a more distal external focus, than that of a visual-ball focus, which was assumed to generate more of a proximal external focus, a 2 Group (visual-ball focus, visual-hole focus) x 3 Attentional Focus Subscale (distal external, proximal external, internal) mixed factor ANOVA was performed, specifically for putts made during the control condition. An interaction effect of Group by Attentional Focus Subscale was significant $F(2,56) = 4.50$, $p = .015$, $\eta_{p^2}=.138$. Fischer's LSD post-hoc analysis showed that participants had a significantly higher proximal external focus in the visual-ball focus group compared to the visual-hole focus group, whereas the visual-hole focus group was significantly higher than the visual-ball focus group for distal external focus. Furthermore, the internal focus of participants in the visual-ball focus group was significantly higher than that of the visual-hole focus group. The relevant descriptive statistics are presented in Table 3.

Table 3

Attentional Focus of Participants in the Control Condition

	Group	
	Visual-Ball Focus	Visual-Hole Focus
Attentional Focus	*M(SE)*	*M(SE)*
Distal External	3.30 (0.25)	3.83 (0.25)
Proximal External	3.74 (0.23)	3.01 (0.23)
Internal	3.49 (0.28)	2.77 (0.28)

Note: Higher scores are indicative of more attention in this sub-category. *M = mean. SE = standard error*

There was no significant three-way interaction between Group, Condition, and Attentional Focus Subscale, however, Table 4 shows us that the task-irrelevant condition worked as desired. Participants focused on internal factors significantly more in the task-relevant condition than the control or task-irrelevant conditions, for both groups.

Table 4

Means and Standard Errors for Participants' Attentional Focus

	Group					
	Visual-ball			Visual-hole		
Attentional Focus	C	TI	TR	C	TI	TR
Distal External	3.30 (0.25)	2.96 (0.27)	3.21 (0.30	3.83 (0.25)	3.21 (0.27)	3.40 (0.30)
Proximal External	3.74 (0.23)	3.54 (0.27)	3.68 (0.24)	3.01 (0.23)	3.07 (0.27)	3.21 (0.24)
Internal	3.49 (0.28)	3.20 (0.22)	4.01 (0.23)	2.77 (0.28)	2.76 (0.22)	3.69 (0.23)

Note: Higher scores are indicative of more attention in this sub-category. *C = control condition. TI = task-irrelevant condition. TR = task-irrelevant condition.*

Putting Performance

Mean Radial Error (MRE).

There was no main effect of Group on MRE $F(1,28) = 0.19$, $p = .664$, $\eta_{p^2} = .007$. The main effect of Condition $F(2,56) = 2.82$ on MRE approached significance, $p = .068$, $\eta_{p^2} = .092$. The putting performance under task-relevant conditions had a higher error score ($M = 3.80$, $SE = 0.27$) than those under task-irrelevant ($M = 3.39$, $SE = 0.27$) or control ($M = 3.41$, $SE = 0.29$) conditions. The main effect of Block $F(3,84) = 2.43$ on MRE also approached significance, $p =$

.071, η_{p^2}= .080. This strong trend indicated that the highest error score occurred in the first block and this error decreased the most by the second trial block, with fairly consistent performance afterward. Means (with standard errors in parentheses) for Blocks 1 through 4 were 3.92 (0.27), 3.47 (0.33), 3.36 (0.29), 3.39 (0.27). Analyses conducted with outlier scores removed also showed no significant main effects.[1] While the participants in the visual-hole focused group showed a greater decline in performance (Mean difference = 0.63) between the control condition and task-relevant condition than that of the ball-focused group (Mean difference = 0.15) (See Table 5), these results were not statistically significant as there was no Group X Condition interaction.

Table 5

Group by Condition Putting Performance Error

		Group	
		Visual-Ball Focus	Visual-Hole Focus
Condition	Error Measure	*M(SE)*	*M(SE)*
Control	MRE	3.40 (0.41)	3.42 (0.41)
	BVE	1.79 (0.14)	1.84 (0.14)
Task-irrelevant	MRE	3.32 (0.38)	3.46 (0.38)
	BVE	1.77 (0.13)	1.83 (0.13
Task-relevant	MRE	3.55 (0.39)	4.05 (0.39)
	BVE	1.87 (0.14)	2.01 (0.14)

Note: M = mean. SE = standard error. MRE = mean radial error. BVE = bivariate variable error.

[1] No significant main effects or interactions for MRE, but trends for Condition $F(2,52) = 2.34$, $p = .106$, $\eta_{p^2} = .083$ and Block $F(3,78) = 2.16$, $p = .100$, $\eta_{p^2} = .077$ main effects

Bivariate Variable Error.

There was no main effect of Group for BVE $F(1,28) = 0.22$, $p = .642$, $\eta_{p^2} = .008$. Additionally, there was no significant main effect of Condition $F(2,56) = 2.32$, $p = .108$, $\eta_{p^2} = .076$, or Block $F(3,84) = 2.17$, $p = .098$, $\eta_{p^2} = .072$ on BVE. Analyses conducted with outlier scores removed also showed no significant main effects.[2] Similar to MRE results, although the participants who visually focused on the hole showed a greater decline in their performance between the control condition and task-relevant condition (Mean difference = 0.17) than that of the ball-focused group (Mean difference = 0.08), this trend was not significant (See Table 5).

Putts Made.

There were no significant main effects of Group $F(1,28) = 0.41$, $p = .840$, $\eta_{p^2} = .001$, Condition $F(2,56) = 1.48$, $p = .238$, $\eta_{p^2} = .050$, or Block $F(3,84) = .658$, $p = .580$, $\eta_{p^2} = .023$ on putts made. Similarly, there was no significant interactions between Condition and Block $F(6,168) = 1.76$, $p = .111$, $\eta_{p^2} = .059$.

[2] No significant main effects or interactions for BVE: Condition $F(2,52) = 1.92$, $p = .157$, $\eta_{p^2} = .069$ and Block $F(3,78) = 1.79$, $p = .156$, $\eta_{p^2} = .064$ main effects

Chapter 5: Discussion

Optimizing performance has always been of interest to motor performance researchers. Specific to golf putting performance, one domain of interest relates to the visual focus of golfers during a putt and how this affects their putting performance. A small number of experiments have compared one group who looked at the ball versus another group who looked at the hole, with most of these experiments showing no significant differences in putting performance between the two groups (Aksamit & Husak, 1983; Bowen, 1968; Cockerill, 1979; Gott & McGown, 1988). Interestingly, two more recent experiments showed some advantages in the group that visually looked at the hole. Heath et al. (2008) showed this in their putting performance results and Mackenzie et al. (2011) showed this in terms of their putting kinematic results.

Given that these two experiments showed advantages to visually looking at the hole, it was reasonable to propose that similar results could be replicated. Thus, the purpose of this experiment was to examine the putting performance between one group of golfers that were visually looking at the ball versus another group that were visually looking at the hole. Based on previous experimental results, it was hypothesized that performance benefits would be seen in the group that was visually looking at the hole.

While results from the more recent literature suggest benefits to visually looking at the hole while putting, neither of those experiments examined the potential underlying mechanisms to these observed benefits. Based on the vast amount of literature that shows external attentional focus benefits for aiming tasks (Al-Abood et al., 2002; Granados, 2010; Lohse et al. 2010; Marchant et al., 2007; McKay & Wulf, 2012; Wulf et al., 1999; Wulf and Su 2007; Zachry et al., 2005), it was also hypothesized that a visual focus on the hole would lead a golfer to adopt a distal external focus of attention; an attention focus that has been shown to contribute to performance benefits in golf. Interference with being able to maintain a distal external focus, however, was expected to have a negative impact on putting performance. Thus, it was hypothesized that when golfers were required to putt under a condition that induced an internal attentional focus, there would be a greater deterioration in performance for those in the hole-focused group, because they had previously adopted the optimal distal external focus. In comparison, those in the ball-focused group were expected to have adopted the less optimal proximal external focus, and not show as much performance decline. As such, a significant Group X Condition interaction was predicted for the putting performance measures.

Manipulation Check

As a reminder, a Likert-type manipulation check was administered during experimentation which required participants to respond to a series of nine questions relating to their attentional focus. The questions were divided equally among questions that referred to an internal, proximal external, or distal external focus. There were two main aims of the manipulation check. The first was to determine whether our assumption that the visual-ball focus group would adopt more of a proximal external attentional focus compared to the visual-hole focus group, given that the visual focus was at a proximal point in the environment. As a corollary to this, I also hypothesized that this visual-attentional congruence would be seen for distal external focus, with the visual-hole focus group having a greater distal external focus than the visual-ball focus group. The results of the control condition (Table 3) putts do fall in line with our predictions. Participants had a significantly higher proximal external focus in the visual-ball focus group compared to the visual-hole focus group, whereas the visual-hole focus group was significantly higher than the visual-ball focus group for distal external focus. Interestingly, despite no prediction being stated regarding the internal focus of participants in the control condition between groups, the visual-ball focus group had significantly higher internal focus than the hole-focus group. Thus, the assumptions were supported. That is, the visual-hole focus manipulation did result in golfers adopting a more optimal attentional focus, with heightened distal focus and the least internal focus.

Interestingly, for each Condition under which the golfers putted, the manipulation check data also showed that participants were reporting on adopting all three different types of attentional foci throughout each putt. That is, golfers would simultaneously report a score on the Likert scale that represented that the golfer adopted all three types of attentional foci during that particular putt. We often think of the different types of attentional foci – internal, external – as being mutually exclusive in some sense, however, our manipulation check suggests otherwise as it showed us that golfers could adopt many different types of attentional foci throughout their putts. Despite the putting task having a relatively short duration, it is possible that the golfer considered preparation time before the putt, execution of the putt, and evaluation following contact with the ball as different time points of attentional focus; potentially allowing for attentional focus to shift over time. Indeed, a qualitative study by Bernier, Codron, Thienot, and Fournier (2011) explored the attentional focus of expert golfers using video and interviews. They concluded that golfers used sequences of attentional foci and that they shift over a short period of time from one attentional focus to another when they prepare, execute or evaluate their shot. Also, they claimed that attentional focus is dynamic and adaptive, therefore, static and dichotomous approaches that we typically see in literature are no longer sufficient. The attentional focus manipulation check in the current experiment is in line with these conclusions.

The secondary purpose of the manipulation check was to determine whether the task-relevant condition was operating as desired; i.e., that it did result in golfers attending to body-related actions of the golf putt, thus inducing an internal focus. If this were the case, higher internal scores would occur under this condition compared to the other two conditions. The task-irrelevant condition was used to ensure that differences seen between the control and task-relevant conditions could not be attributed to methodological differences; i.e., the auditory stimulus used during the putt and the participant's choice response following each putt. Therefore, the purpose of the task-irrelevant condition was to serve as a control for the task-relevant condition.

Overall, the significant interaction between Condition and Attentional Focus Subscale indicated that our manipulation check was effective. As shown in Table 2, average response values on the Likert scale for our three internal focus questions in the task-relevant condition were significantly higher than the control condition and the task-irrelevant condition. This tells us that an internal attentional focus was induced when the participants were instructed to focus on their wrists as they putted.

I was also able to check that the control condition and task-irrelevant condition were following the same pattern for each category of attentional focus (distal external, proximal external, internal). Table 4 displays the means and standard errors for the Group X Condition X Attentional Focus Subscale, showing us that the desired patterns do exist. In the visual-ball focus group, for the control condition, attentional focus of participants was most focused on proximal external factors (M = 3.74, SE = 0.23) followed by internal (M = 3.49, SE = 0.28) and then distal external (M = 3.30, SE = 0.25) factors. The same pattern – proximal external > internal > distal external – was shown in the task-irrelevant condition. This shows us that the task-irrelevant condition worked as desired, and thus, the higher internal scores during task relevant putts were related to the golfers being directed to attend to their wrist angle, as opposed to the introduction of a tone during the golf putt.

Putting Performance

It has been suggested in previous literature that as golfers shift their visual focus to the hole, their attentional focus also shifts to a more *external* attentional focus. Heath et al., (2008, p. ix-x) stated that visually focusing on the hole "requires that you focus both visually and mentally on the target – that you really cast your consciousness out to the place where you intend to leave the ball." Indeed, it was this type of suggestion that inspired my research questions posed here. At this point, I have presented data that does show the visual-hole focus group adopts more of a distal external attentional focus while simultaneously having lower internal focus than that of the visual-ball group. Further, it has been shown that the task-relevant condition does increase the level of internal focus attention of golfers.

The fact that both assumptions were met would lead one to think that I would replicate the putting performance results of Heath et al. (2008) in which a visual-hole focus led to better putting performance than that of a visual-ball focus. The putting performance results obtained, however, were similar to of the previous experiments in which no statistically significant results were found between those participants who visually focused on the ball versus the hole (Aksamit & Husak, 1983; Bowen, 1968; Cockerill, 1979; Gott & McGown, 1988). There were however, some trends in the data that fell in line with the hypotheses. I hypothesized that inducing an internal attentional focus would disrupt performance relative to the control condition. For both groups, this appeared to be case. As shown in Table 5, this decrease in performance between the control and task-relevant conditions was greater in the visual-hole focused group (Mean difference = 0.63) compared to the visual-ball focused group (Mean difference = 0.15). This falls in line with the prediction that a greater deterioration would be seen in the visual-hole focused group because they have adopted a *more* external attentional focus than those in the visual-ball focused group. Despite these differences, putting performance scores were not significantly different between groups for each of our three dependant variables. As such, I did not replicate the more recent experiment that showed performance benefits for looking at the hole (Heath et al., 2008), but instead, found similar performance results as the earlier experiments (Aksamit & Husak, 1983; Bowen, 1968; Cockerill, 1979; Gott & McGown, 1988, Mackenzie et al., 2011).

It is possible that methodological factors contributed to our putting performance non-significant findings. In the previous experiment by Heath et al., (2008) performance benefits were seen in the group that was looking at the hole for distances between 3-43 feet. Further, they found that the putts between 28-38 feet showed more benefits that shorter putts between 3-8 feet, which were not significantly different. It is possible that the distance of putt used here was too easy (straight, 10-foot putt) for the experienced golfers (minimum 5 years' experience) whom I recruited. Indeed, the average number of putts made (M = 28.8, SD = 9.7) per 48 experimental trials was relatively high. This high volume of putts made during the experiment may have buffered the error scores to some extent.

The main effect of Block on MRE also approached significance. This implies that despite having 40 warm-up putts and 18 familiarization trials before experimentation, there was still noticeable improvement between Block 1 and Block 2, with error scores staying relatively the same afterwards. There was no significant Group X Block interaction for MRE; however, the visual-hole focus group did show a noticeable decrease in error from Block 1 (M = 4.29) to Block 2 (M = 3.38) whereas the visual-ball focus group remained approximately the same.

The main effect of Condition approached significance for MRE, indicating that putting error was the greatest when an internal focus was induced. This falls in line with the Constrained Action Hypothesis, whereby conscious control of a movement or, an internal focus, disrupts performance. Wulf et al. (2001) have also shown that adopting an external focus of attention allows for a higher degree of automaticity and less conscious interference when compared to an internal focus. In my experiment, it was shown that participants could focus their attention more externally when they were visually fixated on the hole, which should theoretically reduce the amount of conscious effort needed to execute the putts. In turn, this theory would play a role if a participant, or athlete, were to attempt a task in a pressure situation.

Performing in pressure situations has been a widely-discussed topic in previous literature. Masters (1992) has shown that the end-effect of pressure situations, ‘choking’, can be attributed to the reinvestment of controlled processes during performance. An individual will think more about how they are executing a skill when put in a pressure situation. Also, an expert who requires less cognitive effort will be less affected by pressure situations. In my experiment, putting performance was not significantly different between the two Control conditions, however, it would be interesting to see whether these results varied if pressure situations were induced. Theoretically, since the participants who looked at the hole adopted an external attentional focus, which has been shown to use less cognitive effort, they should be less affected by pressure compared participants looking at the ball, resulting in more putts made and less putting error.

Overall, since the main effect of Condition approached significance for MRE, my results replicate the general finding that putting performance is poorest when golfers self-report using a higher internal focus. Specifically, focusing on your wrist angles as you putt has been shown to increase putting error relative to a task-irrelevant and control condition. These results mimic other results that show that inducing an internal focus can disrupt experienced golfers putting performance (Granados, 2010; Kearney, 2014).

Limitations

Recognition must always be given to the limitations of one's experimental design. Certainly, in the case of this research in which data collection occurred in the applied setting of a golf environment, there were limitations imposed by the constraints of this environment. To begin, the outdoor golf environment itself had numerous factors that were impossible to remain perfectly consistent for each experimental session. Air temperature, wind, ground saturation, grass direction, grass length, and natural sounds you can hear outside are just some of the factors that fluctuated between experimental sessions.

As with any mental process, a major limitation is the lack of a 'direct' measure for attentional focus. While it was a strength to include the manipulation check procedure, another limitation was that participants were asked to recall their attentional focus during their "previous putt" instead of a discrete point in time during their putt. As previously mentioned, Bernier et al. (2011) stated that golfers use sequences of attentional foci and that they shift over a short period of time from one attentional focus to another. Despite this interesting concept, not being able to explicitly know where our participants' attention was during specific components of the putting task is a limitation.

Future Research

While the research conducted allowed for a statement to be made about the induced attentional focus imposed on participants, the results did not allow for a confident conclusion regarding putting performance. As previously mentioned, the task that was used in this experiment may have been too easy for participants for performance differences to be seen between groups. Future research could use similar attentional focus conditions as the current experiment, but use a task that is more difficult for participants, resulting in greater error measures and more missed putts.

Seeing as participants in the visual-hole focus group had high error scores in the first block of experimental trials compared to the rest, it is possible that not enough practice or familiarization putts were given. Future research would be encouraged to provide participants with enough of a warm-up that they become fully comfortable with the experimental trials that follow.

In a review by Lee and Schmidt (2013), it is stated that a golf shot is a problem-solving process that involves three steps: planning, acting, and reviewing. Also, Bernier et al. (2011) showed us that golfers use sequences of attentional foci during a golf shot. Taking both into consideration, an experimental design that can quantifiably measure the attentional focus of golfers for each component of a golf shot – preparation, action, evaluation – would allow for more concrete evidence in regards to where the golfers' attentional focus is at specific points in time.

It is important to remember that every participant that was recruited had exclusively looked at the ball when they putted. When the participants were assigned to the visual-hole focus group, they received 40 warm-up putts and 16 familiarization trials. Remember, there were no statistically significant differences in putting performance between groups. One group was putting how they normally would (looking at the ball) and the other group received only 56 practice putts before using a new technique (looking at the hole). It makes one wonder whether practicing putting while looking at the hole for a long period of time; i.e., weeks, months, or years, would result in better putting performance. A future experiment could use a similar experimental design as the current one, but test to see whether *learning* occurs after a certain amount of practice sessions.

Conclusion and Implications

The results suggest that visually focusing on the hole while putting does induce more of a distal external attentional focus compared to visually focusing on the ball. Visual and attentional congruence was found for both the visual-hole focus and visual-ball focus groups. Regardless of the current experiment not finding significant performance results, there is still evidence in previous literature that states inducing a distal external attentional focus is optimal for performance (Bell & Hardy, 2009; McKay & Wulf, 2012; McNevin et al., 2003; Porter et al., 2012). Thus, visually focusing on the hole may certainly be beneficial to golf putting performance, but distinguishing when and how to use this technique may need to further be investigated.

To explain advantages associated with adopting an external attentional focus, Wulf et al., (2001) constructed the Constrained Action Hypothesis in which an internal attentional focus is thought to induce conscious control of the movement, which is argued to be less effective than automatic control mechanisms for movement. The results in the current experiment reinforce this hypothesis, since our participants' putting error did increase when an internal attentional focus was induced. Therefore, practical implications of the research can be directed to players and coaches. For golf players, they should avoid focusing their attention on internal factors; i.e., wrist angles, grip pressure, shoulder movement, as it can be detrimental to putting performance.

Moreover, coaches need to provide instructions that direct a golfer's attention to distal external factors, as opposed to bodily movements, a practice still widely used today.

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Appendix B1

1

2

3

Appendix B2

1

2

3

Appendix C

1

2

3

Appendix D

Demographic Questionnaire

Name: ____

Date of birth (M/D/YR): ____

1. How many years have you been playing in golf? ___________________________

2. What is your current Golf Canada Index/Factor? ___________________________

3. How often do you practice golf putting? _________________________________

4. How often do you play a round of golf? _________________________________

5. Do you look at the golf ball when you putt? ______________________________

Appendix E

Putting Technique Response

To what extent would you be willing to try a new putting technique, which differs from the traditional method you currently use? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

Appendix F1

Participant Number: _________

Block	Putt Number	Condition	Error Coordinates (x, y)
1	1	TI	
	2	TR	
	3	C	
	4	TI	
	5	TR	
	6	C	
	7	C	
	8	TI	
	9	TI	
	10	TR	
	11	C	
	12	TR	
2	13	C *	
	14	C	
	15	TR *	
	16	TI *	
	17	TR	
	18	TI	
	19	C	
	20	TI	
	21	TR	
	22	C	
	23	TR	
	24	TI	
3	25	TI	
	26	TR	
	27	TI	
	28	C	
	29	TR	
	30	TI	
	31	C	
	32	TR	
	33	C	
	34	TI	
	35	TR	
	36	C	
4	37	TI *	
	38	C *	
	39	TR *	
	40	TI	
	41	TR	
	42	TI	
	43	TI	
	44	C	
	45	C	
	46	TR	
	47	TR	
	48	C	

(*) Indicates Attentional Focus Manipulation Check Questionnaire will be administered following putt.

Appendix F2

Participant Number: _________

Block	Putt Number	Condition	Error Coordinates (x, y)
1	1	TI	
	2	C	
	3	TI	
	4	TR	
	5	TR	
	6	TI	
	7	C	
	8	TI	
	9	TR	
	10	C	
	11	TR	
	12	C	
2	13	TR *	
	14	TI *	
	15	TR	
	16	C *	
	17	TR	
	18	C	
	19	C	
	20	C	
	21	TI	
	22	TI	
	23	TR	
	24	TI	
3	25	TI	
	26	TR	
	27	C	
	28	TR	
	29	TI	
	30	TR	
	31	C	
	32	C	
	33	TI	
	34	TI	
	35	TR	
	36	C	
4	37	C *	
	38	TR *	
	39	TI *	
	40	TI	
	41	C	
	42	C	
	43	TI	
	44	TR	
	45	TR	
	46	C	
	47	TI	
	48	TR	

(*) Indicates Attentional Focus Manipulation Check Questionnaire will be administered following putt.

Appendix F3

Participant Number: _________

Block	Putt Number	Condition	Error Coordinates (x, y)
1	1	TI	
	2	C	
	3	TI	
	4	TI	
	5	TR	
	6	TR	
	7	C	
	8	C	
	9	TI	
	10	C	
	11	TR	
	12	TR	
2	13	TI *	
	14	TR *	
	15	TI	
	16	TI	
	17	C *	
	18	TR	
	19	TR	
	20	TI	
	21	TR	
	22	C	
	23	C	
	24	C	
3	25	TR	
	26	C	
	27	TI	
	28	TI	
	29	TI	
	30	C	
	31	TI	
	32	TR	
	33	TR	
	34	C	
	35	TR	
	36	C	
4	37	TR *	
	38	TR	
	39	TI *	
	40	TR	
	41	TI	
	42	C *	
	43	TI	
	44	TI	
	45	C	
	46	TR	
	47	C	
	48	C	

(*) Indicates Attentional Focus Manipulation Check Questionnaire will be administered following putt.

Appendix G

Attentional Focus Manipulation Check

1. To what extent were you focusing on the ball going to the bottom of the hole? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

2. To what extent were you focusing on the ball rolling over the lip into the hole? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

3. To what extent were you focusing on the path of the ball near the hole? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

4. To what extent were you focusing on the path of the ball soon after putter contact? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

5. To what extent were you focusing on the putter contacting the ball? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

6. To what extent were you focusing on the motion of the putter head? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

7. To what extent were you focusing on your hand pressure on the putter? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

8. To what extent were you focusing on your grip pressure on the putter? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5

9. To what extent were you focusing on your wrist angle as you putted? (Circle one answer)

Not at all	Not really	Undecided	Somewhat	Very much
1	2	3	4	5