The Perceptual Motor-effects of the Ebbinghaus Illusion on Golf Putting

by

Victoria Coon

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved March 2019 by the
Graduate Supervisory Committee:

Robert Gray, Chair
Rod Roscoe
Russ Branaghan

ARIZONA STATE UNIVERSITY

May 2019

ABSTRACT

Previous research has shown that perceptual illusions can enhance golf putting performance, and the effect has been explained as being due to enhanced expectancies. The present study was designed to further understand this effect by measuring putting in 3 additional variations to the Ebbinghaus illusion and by measuring putting kinematics. Nineteen ASU students with minimal golf experience putted to the following illusion conditions: a target, a target surrounded by small circles, a target surrounded by large circles, a target surrounded by both large and small circles, no target surrounded by small circles and no target surrounded by large circles. Neither perceived target size nor putting error was significantly affected by the illusion conditions. Time to peak speed was found to be significantly greater for the two conditions with no target, and lowest for the condition with the target by itself. Suggestions for future research include having split groups with and without perceived performance feedback as well as general performance feedback. The size conditions utilized within this study should continue to be explored as more consistent data could be collected within groups.

TABLE OF CONTENTS

Page

LIST OF FIGURES

INTRODUCTION

Golfers, of experience levels from novice to professional, are always attempting to obtain better putting performance. This research investigates how practicing putting with a perceptual illusion can affect one's putting performance. Ebbinghaus Tightener Circles are a perceptual illusion in which small circles (5cm in diameter each) are placed around a target circle (10.8cm in diameter) in one condition, and large circles (15cm in diameter each) are placed around a target circle (10.8cm in diameter) in the other condition (Chauvel et al., 2014, p. 718). See Figure 2 conditions B and C for an image of the large and small circle illusions. The small circles tend to make the target circle look larger compared to a target circle on its own whereas the larger surrounding circles tend to make the target circle look smaller.

Past research found that this illusion affects putting performance (Chauvel et al., 2014, p. 718). Specifically, a perceived larger hole, improves putting (ball closer to the hole) compared to a perceived smaller hole. This performance effect has been explained in terms of increased expectancies because participants feel they are putting into a larger hole, that they are going to putt better with the towards the larger hole, and so they do. Chauvel (2014) and associates state that "manipulations that enhanced learners' expectancies for performance success or made a task seem less intimidating have been found to facilitate learning" (Chauvel et al., 2014, p.717). Chauvel (2014) and associates only use the putting greens with the small circle illusion which is 8 small circles surrounding a 10.8cm target circle, and a large circle illusion which is 6 large circles surrounding a 10.8cm target circle. There is no control target within the study, so there is no way to see if the illusion improves putting performance; it only shows that

performance is better in the small circle condition than in the large circle condition. Chauvel (2014) suggests there will be an effect of performance based solely on the expectation of the participants and based on the illusion type; small holes surrounding the golf hole will enhance performance and large holes surrounding the golf hole will hinder performance.

According to past research, when asked to draw the perceived target circle size, participants perceive the target surrounded by smaller holes, to be larger than that surrounded by larger holes (Chauvel et al., 2014, p. 719). Past research has also shown that putting performance is significantly better when putting to a target that is perceived to be larger (Chauevel et al., 2014, p.719). The present study focuses on the enhancements of performance within conditions including the Ebbinghaus and manipulating the Ebbinghaus into more conditions. This is done to understand whether improved performance is due to enhanced expectations as is theorized in Chauvel's (2014) study, or not.

LITERATURE REVIEW

The Ebbinghaus illusion was discovered by Hermann Ebbinghaus, a psychologist whom studied the psychology of memory (Martinez-Conde & Macknik, 2010, p. 2). Several studies show that perception of the illusion size and perception of performance enhances certain tasks, in golf (Witt et al., 2008; Whitt et al., 2012; Chauvel et al., 2015).

Witt theorized that "putting perception may not be a function of how good a player is, but how well they putted in that moment". This is a crucial observation because long term effects are assumed from other studies and they may not be correct (Witt, 2008, p. 3). Witt (2012) and associates conducted yet another study, like their and Chauvel's

(2014) past work. Within this study, Witt et al., (2012) had participants putt to two different sized holes, one smaller being 5.08cm in diameter and the other larger being 10.16cm in diameter. Each target was surrounded by the Ebbinghaus illusion, in which they did not manipulate the size of the surrounding circles to compensate for the larger and smaller target. Similar to Witt's original study, participants were asked draw in Microsoft Paint, the perceived size of the target to which they were putting. They then had them putt 10 times to each condition, 5cm target surrounded by the large circles and small circles simulating the Ebbinghaus illusion, and the 10cm target surrounded by the large circles and small circles simulating the Ebbinghaus illusion. After analyzing the results, Witt and associates found that the perceived size of the smaller 5cm target was influenced as was the putting performance to this condition, however, the size of the 10 cm hole was not influenced. Following these findings, they utilized the 10cm hole as the control in their analysis, and after doing so expected from their findings that putting to the 5cm hole was due to the perceived size of the target, and not directly due to factors of the surrounding circles creating the illusion. This suggest that better putting performance with the larger hole was due to an increase in perceived target size and confidence, which they expect improved the participants performance. (Witt et al., 2012, p. 398). This research assumes that even without outside performance feedback being given, participants confidence increases positively due to their perceived performance.

Chauvel and associates (2014) conducted a similar study utilizing putting tasks and the Ebbinghaus Illusion. They found that when learners in a golf setting are given feedback when they perform well in a task and given no feedback when they perform poorly in a task, that those given feedback and putting into the larger perceived hole size

self-rated higher putting efficacy than those looking at the perceived smaller hole. Those that self -rated higher putting efficacy into the larger perceived hole size condition performed better during the post-test (Chauvel et al., 2014, p. 720) . It is believed that is because motor performance may "be influenced by one's beliefs or performance". It was also found within this study that retention of performance was enhanced during the post-test the day after the practice shots were made with the larger perceived hole than with the smaller perceived hole.

Canal et al., (2016) conducted a study similar to that of Chauvel (2014) but using a task of rolling marbles to a target instead of golf putting. They conducted 2 test phases, pre and post, as well as 3 training phases, 1,2, and 3. They randomly divided the training phases amongst 3 groups. The pre and post tests were comprised of 50 shots each, while the training was comprised of 150 shots per session. The pre and posttests had all participants shoot to the same conditions, the control (one target), the larger perceived target surrounded by small circles, as well as the smaller perceived target surrounded by large circles. Within this study they predicted the opposite to Chauvel et al (2014): "from a motor control perspective…the opposite occurs…if a target is perceived as being smaller (and more difficult to hit) than it is…then performers need to be more precise…allows less variance in putting execution as they may predict the ball to otherwise miss the target area" (Canal et al., 2016, p. 385,). This means that they predict the control and smaller perceived hole conditions to perform better than those with the larger perceived hole. Prior to completing each task, participants were asked to indicate which of 9 circles on a poster were identical in size to the target they were being exposed to, versus asking them to draw the perceived target size as done in both the Witt

(2008;2012) and Chauvel (2014) studies. Within this study they also gave extensive performance feedback from letting participants know how they did after each test and training along with asking them to self-rate their performance. The results from this study supported their hypothesis as the perceived smaller hole condition yielded significantly better performance than the perceived larger hole which is in direct contrast to the findings from the Chauvel (2014) and Witt (2008;2012) studies.

Palmer (2016) and associates conducted a study not utilizing the Ebbinghaus illusion, but instead having conditions including a target circle being surrounded by a large 14cm circle, and a target circle being surrounded by a smaller 7cm circle. They split their participants into groups after having them conduct practice putts and had each group practice by putting to either the small circle condition or the large circle condition, and then had them putt the day following practice to measure retention as well as a transfer task. For the practice conditions, they told participants that a "good" putt constituted as anything that made it into either the small or large circles, otherwise gave no performance feedback. They expected that those that putt to the large circle condition would outperform those that putt into the small condition both in practice as well as in the retention and transfer tasks. Within their data analysis, Palmer (2016) and colleagues found that those in groups practicing putting to the large circle condition outperformed those practicing to the small condition in practice, retention and transfer. They proposed that these findings occurred due to the two factors of performance. The first being that confidence increases when people perform well, and those practicing in the large circle condition had a higher chance of making the putts. The second assumed factor is that those practicing to the smaller condition had a "lack of perceived success" due to the

condition being a harder one to putt to, and thus were affected by their conscious effort to control their putting action which decreased their performance.

Aglioti and colleagues (1995) argue that it may not be as straightforward as perception of self, or perception of the illusion, but that the mind sees the illusion to be closer (smaller) or more distant (larger). This may be the "perceptual system's attempt to make size-constancy judgments on the basis of an analysis of the entire visual array".

Wulf and Lewthwaite (2016) have proposed the OPTIMAL (Optimizing Performance through Intrinsic Motivation and Attention for Learning) theory as a new way to conceptualize some of these effects. See Figure 1 for a visual of OPTIMAL theory. This theory states that "motor learning cannot be understood without considering the motivational and attentional influences on behavior". From past and recent research, Wulf and Lewthwaite (2016) conducted a review converging old and new theories. They propose that there are many forces which affect learning. These include, enhanced expectancies, perceived performance, self-efficacy, self-talk, and external focus of attention. Wulf and Lewthwaite (2016) state that an advantage to focusing on something external such as a goal or target, instead of having an internal focus, that one is able to concentrate on that external goal or target and thus make the intended action. This coincides with the present study, as participants are asked to putt to a target without getting any practice or attention towards their internal movement, and to just focus on the external target. Wulf and Lewthwaite (2016) find it is important to have an external focus as it extremely important for successful motor performance in related tasks. They state that external focuses are more natural to humans, and that as humans have progressed over time, they have forgotten to focus on the external elements and allow human nature

to take over, thus have decreased in their perception of performance as well as decreased in their actual overall performance. Wulf and Lewthwaite (2016) state the following; "It is hard to imagine other animals moving affirmatively for food or survival with a constant internal conversation regarding how to move their limbs most effectively" (Wulf &Lewthwaite, 2016, p.1402). Wulf and Lewthwaite (2016) predict that by utilizing the OPTIMAL theory, goals and movement will be coupled to aid in successful performance, and expectancies will become more positive which will indicate a positive internal dopaminergic response. They believe that with this internal dopaminergic response, motor performance will increase, and thus overall performance will increase.

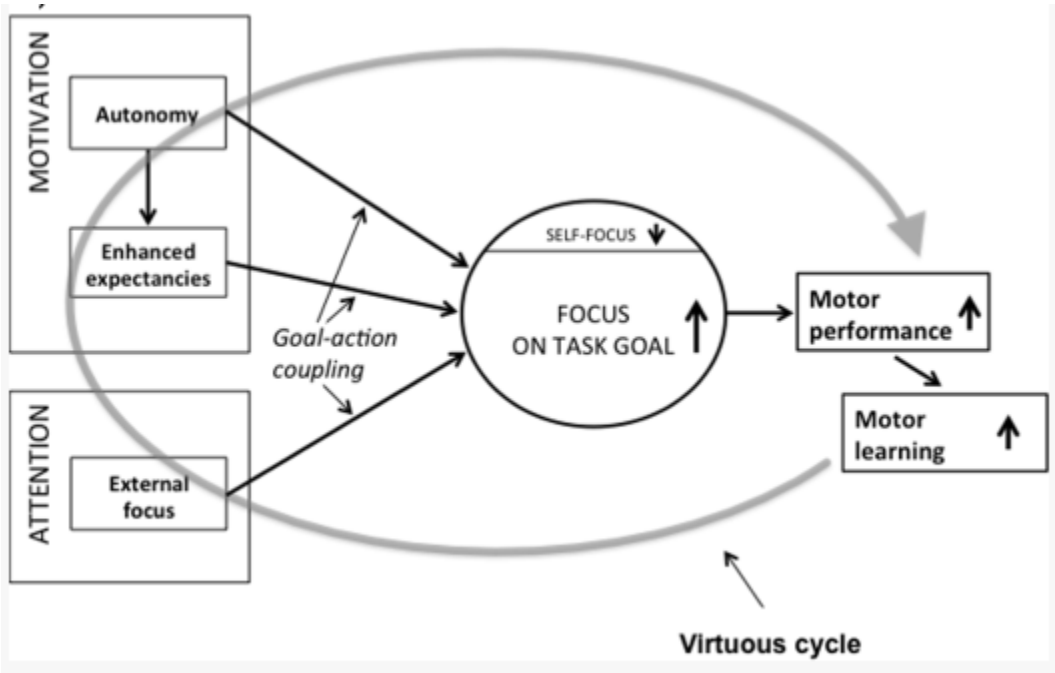

Figure 1. This figure visualizes the OPTIMAL theory which indicates that "conditions that enhance expectancies, provide autonomy support, and promote an external focus result in a virtuous cycle of enhanced motor learning". (Wulf & Lewthwaite, 2016, p. 1405).

Overview

Previous research has consistently found that the Ebbinghaus illusion can affect putting performance. While the bulk of the research has shown that performance is better for a perceived larger target, there have also been some contradictory findings. There are several different proposed explanations for the effects of the illusion on performance including enhanced expectancies, increased confidence, increase perceived performance, differentiation in the perceived target size, and changes in the perceived distance. With this being said, the exact mechanism underlying the cause of improved performance is still somewhat unclear. The goal of the present study was to further our understanding of these effects by expanding on the conditions that have been tested. In the present study, t participants putt to the 6 conditions in a randomized order. There was no external feedback given on their performance either by reassurance or help in putting more accurately. Six conditions (shown in Figure 2) were used:

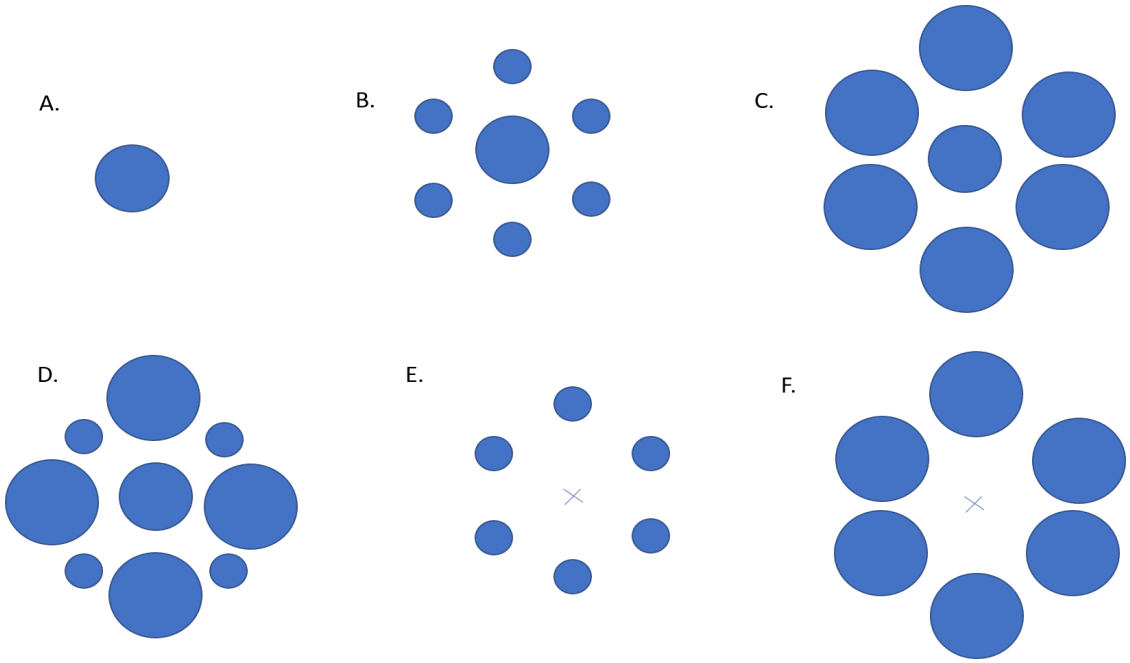

Figure 2. represents the 6 conditions that participants putted to. Condition A. was the control. Condition B. is perceived to have a large center circle. Condition C. is perceived to have a small center circle. Condition D. should have the same perceived size as the control. Conditions E and F have no target.

In the above figure, conditions B and C are similar to those tested in previous research by Chauvel et al., (2014) and Witt et al., (2008;2012). The target only, condition A, was added to determine if putting performance is actually improved relative to a no illusion condition. Conditions E and F were included to determine if the presence of the outer circles influence putting if they do not have any influence of the perceived size of the central target. Finally, Condition D was included as an addition control, since large and small outer circles are used there should be no illusory change in the size of the central target.

In addition to testing different conditions, the present study added to previous research by measuring the effect of illusion on putting kinematics. Specifically, time to peak speed which can be defined as the time in which the head of the putter meets the golf ball during the downswing (Gray et al., 2012, p. 387), was measured for all putts. Putting performance should be worst in condition C (since the perceived hole size is smaller), and similar for all other conditions since they would presumably not invoke a change in perceived target size.

METHODS

Participants

Arizona State University students (n=19, 14 male, 5 female, M_{age} = 21years, age range = 18-32) participating in HSE or PSY 101 were recruited using the SONA System, and asked to participate in this study. All participants completed each of the 6 conditions within this study in a randomized order. Participants were compensated in the form of 1 credit hour for either PSY 101 or HSE 101. All participants had a self-rated golf skill

level from none to beginner. Procedures were conducted in accordance with ASU's Institutional Review Board, consent forms were collected from each participant before being a part of the study.

Materials

The study followed within-subjects design with putting condition as the independent variable. All participants participated in all 6 conditions, each in a randomized order. The study was designed with the simulated illusions using black felt circles stuck to a fake putting green. For each putt, the ball was positioned on a strip of black duct tape placed 2.5 meters from each condition. Referring to Figure 2 above, condition A was a 10.8cm felt target circle. Condition B was 6 "small" 5cm circles surrounding the 10.8cm target circle. Condition C was 6 "large" 15cm circles surrounding the 10.8cm target circle. Condition D was a mix of 4 "large" 15cm circles alternating with 4 "small" 5cm circles surrounding the 10.8cm target circle. Condition E was 6 "small" 5cm circles surrounding a 1cm target circle which represented no target. Condition F was 6 "large" 15cm circles surrounding a 1cm target circle which again, represented no target. An inMotion motion sensor was attached to the back of the putter to measure putting kinematics. Microsoft PowerPoint was used to evaluate the participants perceived size of the target circle.

Procedure

All testing was carried out in October of 2018. Participants came to the lab in which the study was conducted and participated in one session lasting 30-45 minutes. Upon arriving, participants self-rated their golf skill level from "none" to "advanced". Once participants filled out all necessary consent and demographic information, they were asked to practice putting 10 times towards the control target (A in Figure 2) to get

comfortable putting. These putts were not measured. Following practice putts, participants were asked to turn around to face the opposite wall of the target for the moderator and observer to change the condition, this was done following each condition. Once the condition was set up, the participant was asked to draw the perceived size of the central, target circle in PowerPoint. They were asked to do this for conditions A, B, C and D. Conditions E and F contained no target; thus, participants were not asked to draw the perceived target size for those conditions. The participants were asked to draw the perceived target size to see if there is any correlation between their putting performance, and the perceived size of the target. Once the participant drew the perceived target size, they were asked to putt 10 times towards the center of the target. For conditions A-D, participants were told that their goal was to putt the ball as close as possible to the center of the central, target circle. For conditions E and F, they were told that their goal was to putt the ball as close as possible to a small (1cm) circle place in the center of the ring of circles (as indicated by the 'X' in Figure 2). Following each putt, the distance of the ball from the center of the target was measured in centimeters. The movement of the putter during each putt was measured to gauge "time to peak speed" or "TTPS" for each condition. Each participant was presented a condition in randomized order until they had putted to each condition. The mean distance from hole, drawn circle diameter and TTPS were calculated by averaging for the 10 putts in each condition. These data were then analyzed using separate one-way ANOVAs with condition as the factor.

RESULTS

Figure 3 shows the mean diameter of the perceived target size drawn in Microsoft PowerPoint for each of the four conditions with a central target. To further illustrate,

figure 4 shows a visualization of the mean perceived size. To evaluate whether or not there was a significant effect on perceived hole size for conditions A, B, C and D, a repeated measures ANOVA was conducted. Mauchly's test of sphericity showed that sphericity was violated as $X^2(5)=13.8$, $p=0.17$, therefore the Greenhouse Geiser estimates of sphericity was used. The ANOVA revealed that there was no significant effect of condition on perceived target size, $F(2.14,28.98)=.901,p=.199$.

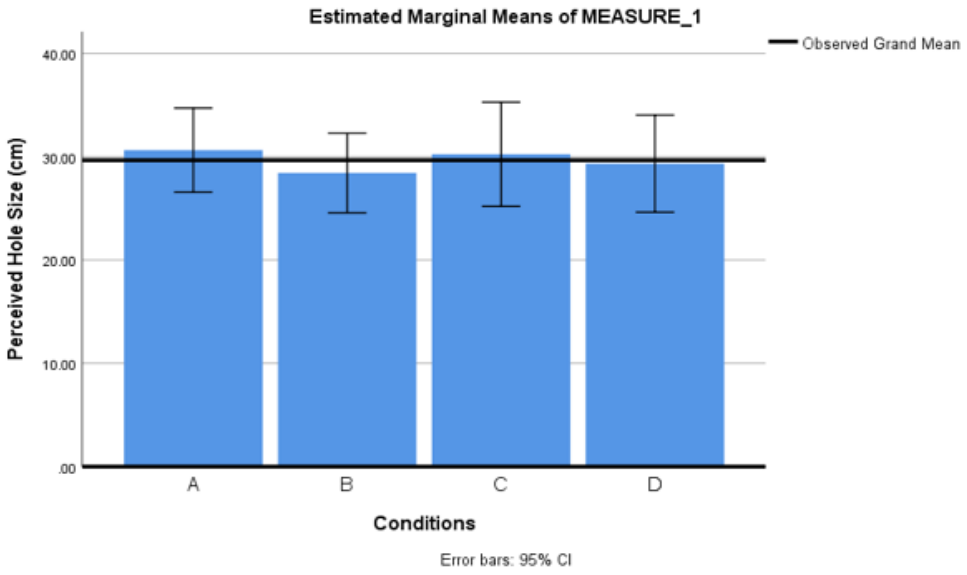

Figure 3. Estimated marginal means of perceived hole size, with error bars and the observed grand mean.

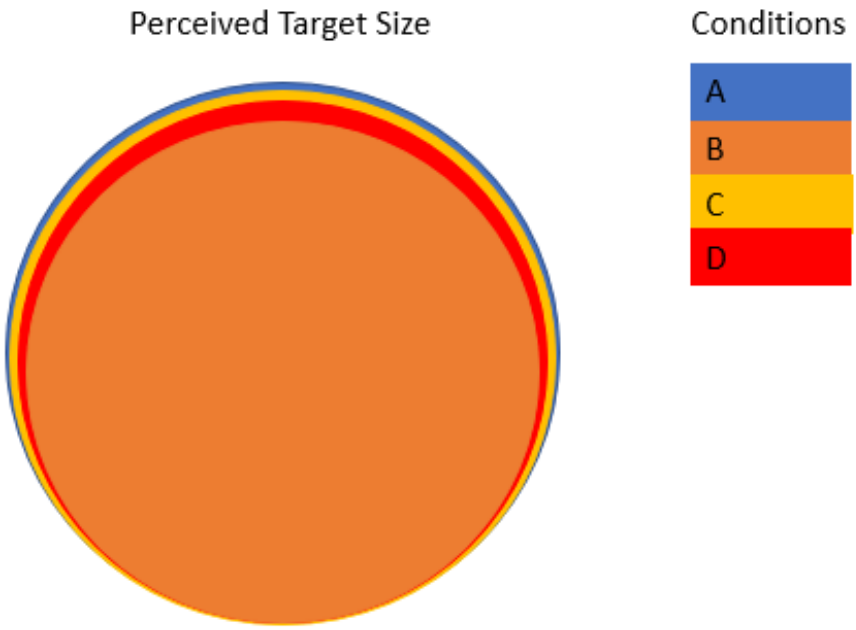

Figure 4. A visualization of the mean perceived target size. See corresponding legend to for condition.

Figure 5 shows the mean distance of the ball from the center of the target for each of the six putting conditions. A one-way ANOVA performed on these data revealed no significant effect of condition, $F(5,108)=.592, p=.736$.

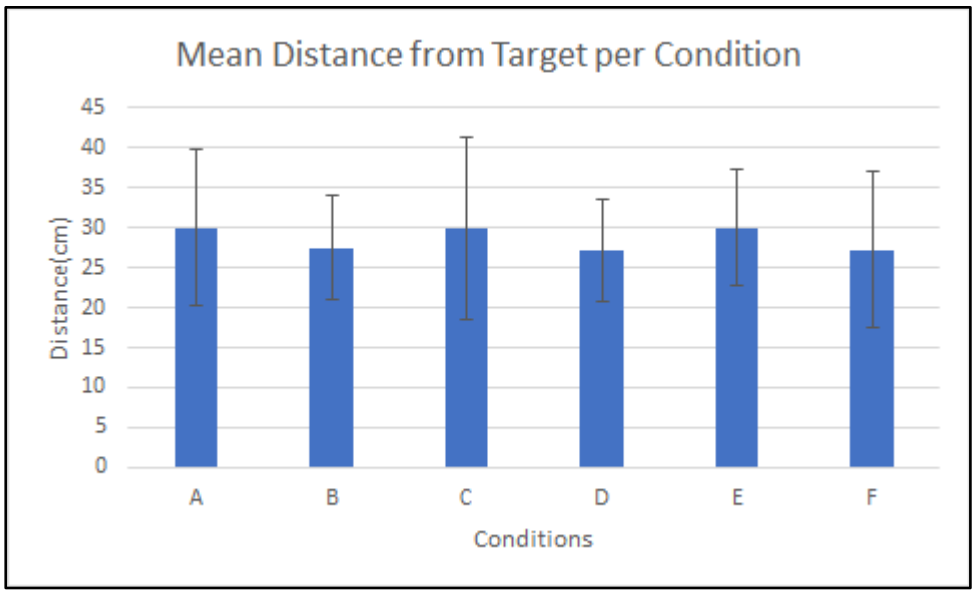

Figure 5. Figure five shows the mean comparison of the distances from the target per condition. Conditions B, D and F had the lowest mean distance, where conditions A, C, and E had the highest. These findings are not significant because the difference in means is approximately 3 centimeters.

Figure 6 shows the mean TTPS for the six putting conditions. The ANOVA performed on these data revealed a significant effect of putting condition, ($F(5,108)=8.92, p=.000$). A Tukey post hoc test revealed that that the time to peak speed was significantly lower when putting in conditions C(.338+/-.0311,p=.040), D(.354+/-.0373,p=.001), E(.370+/-.0375,p=.000), F(.370+/-.0315,p=.000) when compared to condition A(.293+/-.0805). There was no statistically significant difference between Condition A and Condition B (p=.747). When compared to condition B, time to peak speed was significantly lower after time to peak speed when putting in conditions E(.370+/-.0375,p=.003), F(.370+/-.0315,p=.003). There was no statistically significant difference between conditions B and A(p=.747), C(p=.591) and D(p=.076). When compared to condition 3, time to peak speed was significantly lower when putting in condition A(.293+/-.0805, p=.040). There was no statistically significant difference between conditions C and B(p=.591), D(p=.870), E(p=.246) and F(p=.246). When compared to condition D, time to peak speed was significantly lower when putting in condition A(.293+/-.0805, p=.001). There was no statistically significant difference between conditions D and B(p=.076), C(p=.870), E(p=.890), F(p=.890). When compared to condition 5, time to peak speed was significantly lower when putting in conditions A(.293+/-.0805, p=.000), and B(.314+/-.0368, p=.003). There was no statistically significant difference between conditions E and C(p=.246), D(p=.890) and F(p=1.0). Lastly, when compared to condition F, time to peak speed was significantly lower when putting in conditions A(.293+/-.0805, p=.000), and B(.314+/-.0368, p=.003). There was no statistically significant difference between F and C(p=.246), D(p=.890) and E(p=1.0).

Within this data analysis, the results indicate that Condition B had the overall lowest mean TTPS, and Conditions E and F the overall highest mean TTPS.

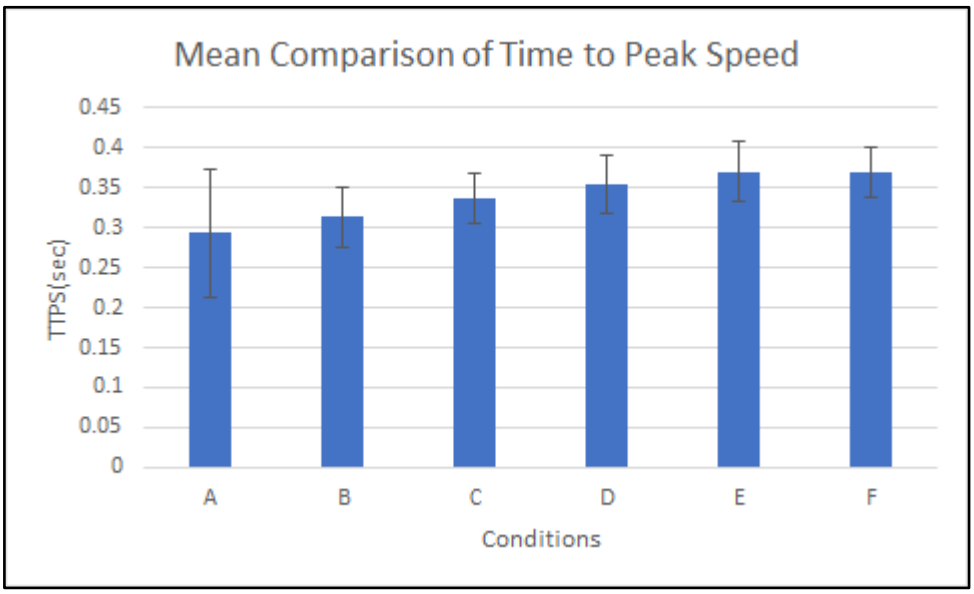

Figure 6. This figure shows the mean comparison of time to peak speed for each condition. Condition A having the lowest mean TTPS at ~.293 seconds, Condition B having a mean TTPS of .314, Condition C having a mean TTPS of .338, Condition D having a mean TTPS of .373, Condition E and Condition F having the highest mean TTPS of .370.

DISCUSSION

The present study was designed to further explore the effect of the Ebbinghaus illusion on putting performance by testing addition conditions and measuring putting kinematics. Witt et al., (2008;2012), Chauvel et al., (2014), and Palmer et al., (2016) all propose that perceived performance, perceived hole size and feedback may enhance one's ability to learn and practice utilizing the illusion and that these performance expectancies may enhance retention and as well as performance transfer. It was predicted within this study that putting performance should be worst in condition C (since the perceived hole size is smaller), best in condition B (since the perceived hoe size would be larger) and similar for all other conditions since they would presumably not invoke a change in perceived target size. The quantitative data discovered that the most significant factor between conditions was found within the measure, time to peak speed, which is the time between the peak of the backswing and when the head of the putter hits the ball in the downswing (Gray et al., 2013, p. 387).

The quantitative data measured on both the distance from the target as well as the perceived hole size, were not significant within the conditions. Though these were not significant measures within the study, the general patterns observed within the distance from the target matched that of the predictions of the present study. This is a contradiction to past research, because there was clear significance in studies conducted by Witt et al., (2008;2012), Chauvel et al., (2014), and Palmer et al., (2016). These studies should continue to be tested and questioned, because replication of findings in this setting was not the case in the present study. Future research may aid in indicating the

true significance of these measures utilizing a larger sample size as well as pre and post-tests.

These results did not support the hypothesis, nor did they support past research. Both the present study's hypothesis, as well as past research, indicated that that the condition B with the perceived target hole would yield the best performance, and condition C with the perceived smaller hole did not yield the worst performance. Neither was supported within this study, even relative to the conditions in which there was no perceived illusion. The measure taken to measure the distance should be considered in future research, because in the present study the distance from the target to the place the ball lands is measured. This measure is potentially confounding as participants aimed at the target, and it would often graze over the target because of the force of the putt and lack of hole. Future research should consider taking video of each putt and considering the force of the ball using the inMotion sensor, and where the ball hits the target (ie., center, side, not at all). These measures could potentially aid in getting a more accurate understanding of whether the Ebbinghaus aids in training, or if it still yields no significance in putting as found in the present study. Within these findings, it is difficult to interpret the results as there were no significant effects on perceived target size drawn within PowerPoint which suggests that the illusion doesn't work.

The significant effect on TTPS suggests that in some way, the conditions influenced putting performance. The data showed that conditions E and F had a higher TTPS and condition A, had the lowest TTPS. According to Gray (2013), TTPS occurring later is typically associated with more expert/better putting performance, thus this effect occurring when putting with no central target suggests that such conditions should be

explored further. A suggestion for future research would be to focus on whether participants take a longer time to prepare for their shot when the target is “complicated” and surrounded by circles, whereas condition A was simpler as it wasn’t surrounded by anything. By utilizing the iMotion eye trackers in future research, the eye movements of participants can be measured along with their TTPS. This can be done to see if there is any correlation with the quiet eye effect and TTPS, which may aid researchers in understanding why TTPS is lower with condition A and lowest in conditions E and F. Is it because it takes longer to prepare for the putt? Does the participant look at the more “complicated” target more? The reason for this is not entirely known, and further research should be conducted to test these conditions with TTPS measured.

Future iterations of this study should focus on pre-tests, practice and a post-test with retention and transfer as done in the study conducted by Palmer et al., (2016). The present study suggests that within future research, there should be some manipulation to the presentation of the conditions. These may include rotating the way in which the circles are positioned, to see if a clear path through the outer circles surrounding the target versus a circle acting as a barrier in the direct path of the target. This may yield interesting results because in one condition there is a clearer, less barred path in which to putt, and in the other manipulation, there is a barrier (surrounding circle) between the putter and the target. It may also be interesting to see what other modes of life the illusion may affect, and if learning and or training with the illusion can help in target practice, soccer practice, basketball or other such sports and if it truly makes a difference across all boards.

Limitations

Due to limited time and resources, the sample size was smaller than that needed to measure for true significance within the measures being tested; because of this, further research should utilize a larger sample size as well as include a pre and post-test to support and enhance the findings of the present study as was done in previous research (Witt et al., 2008,2012; Chauvel et al., 2014; Palmer et al., 2016). An eye tracking apparatus should be utilized the measure the quiet eye effect, which is defined as "the final fixation or tracking gaze on a specific object or location in space before unfolding of a final movement that is critical to performing successfully" (Klosterman et al., 2013, p. 1270). Acquiring this measure would aid in understanding perceived performance of the participants putting to each condition.

CONCLUSION

"…Manipulations that enhanced learners' expectancies for performance success or made a task seem less intimidating have been found to facilitate learning" (Chauvel et al., 2014, p. 717). The present study suggests that when putting to a target surrounded by various perceptual illusions, the time to peak speed in a putt may be affected. By utilizing these findings, as well as prior research, a study in which time to peak speed is measured alongside motivational self-talk, performance feedback, and no feedback are split between groups presented to the conditions with no central target, may yield interesting and insightful results. These measures seem to be a contender for the reasoning behind enhanced performance, but this won't be known without further research.

REFERENCES

Aglioti, S. (1995). Size-contrast illusions deceive the eye but not the hand. Current Biology, 5(6), 679-680.

Cañal-Bruland, Rouwen. (2016). Can Visual Illusions Be Used to Facilitate Sport Skill Learning? Journal of Motor Behavior, 48(5), 285-390.

Chauvel, Guillaume. (2015). Visual illusions can facilitate sport skill learning. Psychonomic Bulletin & Review, 22(3), 717-722.

Gray, Rob. (2013). Changes in putting kinematics associated with choking and excelling under pressure. International Journal of Sport Psychology, 44(4), 387-408.

Klostermann, A., Kredel, R., Hossner, E., & Enns, James T. (2013). The "Quiet Eye" and Motor Performance: Task Demands Matter! Journal of Experimental Psychology: Human Perception and Performance, 39(5), 1270-1278.

Martinez-Conde, S., & Macknik, S. L. (2010). Visual Illusions. Encyclopedia of Perception, 1-6. doi:10.4135/9781412972000.n344

Palmer, Chiviacowsky, & Wulf. (2016). Enhanced expectancies facilitate golf putting. Psychology of Sport & Exercise, 22(C), 229-232.

Witt, Jessica K. (2008). Putting to a bigger hole: Golf performance relates to perceived size. Psychonomic Bulletin & Review, 15(3), 581-586.

Witt, Jessica K. (2012). Get Me Out of This Slump! Visual Illusions Improve Sports Performance. Psychological Science (0956-7976), 23(4), 397-400.

Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. Psychonomic Bulletin & Review, 23(5), 1382-1414.