Automated Tracking of the Golf Putt: An Analysis of Low Handicap Golfers and Feedback for Novice Golfers

By

Chad Robert Goodall

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

Master of Arts

Department of Psychology
University of Manitoba
Winnipeg, Manitoba

0-612-51716-0

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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Abstract

Golf is a very popular sport, as an endless array of books, articles, and magazines on the topic can attest. Given that putting usually accounts for nearly one half of a golfer's total score (Soley, 1977) it is surprising that the skill of putting is usually not the focus of these information sources. Previous studies on putting used aversive feedback to correct improper movements, or a laser to quantify putter alignment. The present study used an automated tracking system in two experiments. The first experiment was a general test of the system's ability to collect useful data on the putting stroke of 9 low handicap golfers (8 males, 25 to 67 years old, 1, 24-year-old female, mean handicap 9.2). Data were collected on four main variables: initial clubface angle, swingpath angle, putter velocity, and putter acceleration. Analysis showed that two of the variables were significantly correlated to the golf ball's final resting position (swingpath angle $r = .3671$, putter velocity $r = -.3400$, $\underline{p} < .0001$). These two variables were then further analysed to calculate optimal ranges that were most likely to result in putts on target for use in

Experiment 2. The second experiment was a specific test of the system's ability to improve the putting stroke of 2 novice golfers (26-year-old male, 30-year-old female). Using an ABACA design for the two treatment variables, this experiment tested the effectiveness on actual putts of providing feedback on practice putts. Results showed that the feedback resulted in few significant improvements in the number of putts on target, on weight, and on line. However, visual analysis and several least significant difference tests (LSD, $p < .05$) revealed significant improvements on both putter velocities and swingpath angles. Minor difficulties encountered with the current study are discussed, and suggestions of possible alterations for improved future research are provided.

Automated Tracking of the Golf Putt: An Analysis of Low Handicap Golfers and Feedback for Novice Golfers

Introduction

Before getting involved in the details of providing feedback to novice golfers, it is appropriate to trace the path by which this research was arrived at. In doing so, there will be an outline of some research on shaping which spawned the idea. Next, there will be a brief discussion of the reasons for choosing the golf putt as the target response, followed by a summary of the psychological research on golf. Finally, there will be a discussion of the general outline of the study, followed, in the method section, by the detailed description.

Connection to Shaping

Shaping is a method of establishing a new operant response. The process consists of reinforcing successively closer approximations to the target response, while all previous approximations are extinguished (Pear & Legris, 1987; Skinner, 1953). As noted by Pear and Legris (1987), the next approximation that will be reinforced is selected by the experimenter on the basis of his/her previous knowledge about the variations in the response topography. This is a rather imprecise method which is generally intuitive, and more of an art than a scientific procedure (Pear & Legris, 1987).

As a result of this gap in the exact science usually associated with behaviorism, Pear and Legris (1987) developed an automated tracking system that incorporated a computer program to shape certain head movements in pigeons. This approach to shaping is new in that it not only allows for continuous monitoring, but presents a means for finding the optimal shaping procedure. Essentially, two TV cameras were used to track the subject's movements three-dimensionally. This information was then used by a computer to reinforce very precise spatial approximations to a target response. The result, was the successful shaping of a precise head movement in all three pigeon subjects.

Having proven that the system is capable of shaping a response in pigeons, Pear (1997) then decided to investigate whether or not the same results could be obtained with human participants. Although the initial human studies have not been as successful as the original pigeon study, recent, unpublished work has been more fruitful.

To date, most of the research using human participants (Pear, 1997) has been conducted in an environment that in many ways mimics the environment of the pigeon studies (Pear & Legris, 1987). In their most basic form, these studies have required the participant to move a stylus, with a white ball on the tip, inside a black, wire frame cube. While moving the stylus, the participant is reinforced for approaching an invisible, randomly selected, area of the cube. The movements of the stylus, and the delivery of reinforcers for closer approximations of the target response, are all controlled by the computer system. Although this has been a relatively successful approach for developing both the hardware and the software of the system, and for training nonhuman subjects, the target behavior for the human studies has few practical applications. Consequently, the present study will be designed to open the door to human research with potentially useful target behaviors as outcomes.

Although shaping participants to find a point is useful for such tasks as locating items, pointing, pressing buttons, etc. the procedure does not concern itself with the path taken from the starting point to the target area. For many human movements, the path towards the target area is just as important as getting to the target area itself. For example, if a person is throwing a ball and we only shape this person to release his/her grip at a certain location, the ball may travel in any number of directions, depending on the direction the subject approached the target from. In order to have control over the final destination of the ball it is important to have control over the approach to the release point as well as the release point itself. By developing the ability to shape movement patterns, we open the door to shaping more complicated skills such as those found in daily life, in the arts, and in sport.

Conceptually, shaping a movement pattern is not far removed from shaping a response to a single target. In the early studies conducted by Pear and Legris (1987), the target consisted of a small, spherically shaped area of the operant chamber. The target in a movement pattern study can be conceptionalized as consisting of a large number of small, spherical target areas linked together in a specified sequence. As the number of target areas in the sequence increases, the target response area approaches a tube-like shape. A critical step, is to determine what the optimal response shape is.

Why the Golf Putt

The target response chosen for the present study is the golf putt. This response was chosen for several reasons. First, it was desirable to choose a movement that was relatively slow in order to ensure that the tracking system would not encounter too much difficulty following it. In its present state, the system is sometimes unable to precisely track a fast movement. It was also important to choose a movement that was reasonably small, so that it could easily be studied in the confines of the laboratory. For example, a skill such as the javelin throw could not be studied simply because of the spatial confines of the lab. The golf putt was also chosen because of the precise nature of the movement. The small size of the target requires the golfer to be very exacting in his or her movements in order to accurately putt the ball into the hole. Finally, this skill was chosen because of the paucity of psychological research in this area.

Research Review

Although books, magazines, and articles about golf abound, few of the works concentrate on putting. There are books about the PGA tour (Astor, 1991), golf rules (Dobereiner, 1992), golf courses (Gordon, 1991), golf history (United States Golf Association, 1994), golf for women (Lewis, 1990), great players (Nicklaus, 1979), mental aspects of the game (Gallwey, 1981), and extensive books on turf management (Beard, 1982). There are also many books that concentrate on the golf swing. However, much of the information presented concerns use of the driver, tee shots, fairway woods, fairway irons, chipping, sand shots, etc. (Couples & Andrisani, 1994; Palmer, 1993). In comparison, very little coverage is given to putting. For example, only one chapter in the Couples and Andrisani (1994) book, and only a few pages in the Palmer (1993) book, deal with putting. This is surprising given that putting generally accounts for nearly one half of a golfer's total score (Soley, 1977). Further, much of the information is simply gleaned from golf pros or instructors (Couples & Andrisani, 1994; Palmer & Dobereiner, 1986) rather than scientific analysis. When information is more scientifically collected, it is most often purely biomechanical or statistical in nature (Neal & Wilson, 1985; Soley, 1977). Very little research exists on the learning process itself.

Simek and O'Brien (1978). One of the few psychological studies of the golf putt, and the one that is most closely related to the proposed study, was conducted by Simek and O'Brien in 1978. They were concerned with increasing head and body steadiness during the golf putt, since their research indicated that this was one component of proper putting technique. After the experimenters took baseline measurements of the putting accuracy of six golfers, they gave the golfers immediate feedback on their head steadiness during several golf putts. Feedback was presented in the form of a loud click that served as an aversive cue for head movement. The results indicated that there was a significant increase in putting accuracy when the feedback was provided.

This work is important to the present study in that it is the only experimental research in the literature that has used a behavioral technique to modify the putting behavior of golfers. Although a future study may involve the use of the more complicated feedback required for shaping, the present study employed feedback that is somewhat more informative to the golfer than a simple clicking noise contingent on head movement. Immediately following each putt, feedback was given on one of several relevant dimensions and included information on the direction of the errant behavior.

McGlynn, Jones, and Kerwin (1990). A second article that is related to the present study was conducted on the golfer's ability to align the putter so that it is perpendicular to the intended path of the ball (McGlynn, Jones, & Kerwin, 1990). In this study, a laser and mirror arrangement was used to take extremely precise angular measurements of putting alignment. Participants of varying abilities were asked to align several different putter styles at various distances. Results showed that the laser arrangement was very successful in quantifying putter alignment, however no attempt was made to improve the putting ability of the participants.

The present study also included a measure of putter alignment that is similar to that of McGlynn et al. (1990). Although the proposed measure of alignment was not as accurate as the laser setup mentioned above, it may not be necessary to require such precision. In addition, the present measurement system has the added advantage of being able to record data about the actual putting stroke, as well the initial alignment. In the McGlynn et al. study participants completed a putt following the alignment task, however no data was collected on this portion of the skill.

Present Study

The intent of the present study was to extend the feedback of the Simek and O'Brien (1978) study to include information such as measures of angle, velocity, and acceleration. At the same time it was proposed that the stationary measure of alignment be extended to include measures of the putter as it is moved through an actual putting stroke. The additional measures included the initial clubface angle mentioned above, as well as measures of swingpath angle, putter velocity, and putter acceleration.

The study included two experiments, the first of which was similar to the McGlynn et al. (1990) work in that its main goal was to test the system's ability to accurately record data on the putting stroke. For this purpose, low handicap golfers were asked to attempt several putts so that the system could collect data on reasonably correct putting strokes. Once the data was analyzed it was possible to glean some information about the parameters of the correct putt so that these values could be used as targets for comparing the values obtained from beginner golfers. The second experiment was similar to that of Simek and O'Brien (1978) in that feedback was used to attempt to improve the golfer's putting ability. If this proved to be successful, then it may be possible to expand the computer system to use shaping to modify a beginner golfer's putting stroke even more efficiently.

General Arrangement

As mentioned above, this study consisted of two separate experiments. The first experiment was a general test of the system's ability to collect useful data on the putting stroke of several low handicap golfers. The second experiment consisted of a specific test of the system's ability to improve the putting stroke of novice golfers, by providing feedback on the differences between their putt and that of the low handicap golfers.

Apparatus

The experimental room (3.66 m x 7.93 m) contained all of the equipment necessary for the study. The golf putter was a traditional, blade-style putter manufactured by Northwestern (Tom Weiskopf - 311). It had a standard shaft length of 86 cm and could be used by either right or left-handed golfers. However, due to the position of the camera (see below) it was only used by right-handed golfers in this study. The black putter head was given a coat of flat black enamel paint to prevent reflected light from interfering with the tracking system. Although an originally white alignment mark was now black, it was still visible to the golfer as a groove that ran across the top of the putter. The portion of the putter that was tracked by the system consisted of a silver circle (1.2 cm in diameter) that was cut out of a strip of reflective tape (Trim Brite Reflective Tape T-1809). This target was attached to the top side, of the distal end, of the putter head.

The golf balls (Spalding Top Flite XLII) were also painted with flat black enamel paint to prevent reflected light from interfering with the tracking system. Although this was an unusual color for a golf ball, it was not expected to interfere with the golfer's performance because a variety of golf ball colors already exists.

The putting surface was a 1.22 m by 3.66 m (4 x 12 foot) dark green golf carpet manufactured by Executive Link. At one end of the carpet was a target at which the golfer was to aim. It consisted of a circle, 10 cm in diameter, where the carpet had been painted with flat black enamel paint. Although golf usually consists of attempting to get the ball into a hole, or cup, the black circle was chosen as the target because of its higher requirement for accuracy of velocity and to remove the confound of the ball being stopped or deflected from its course by the hole. Thus, the black circle was a "simulated hole".

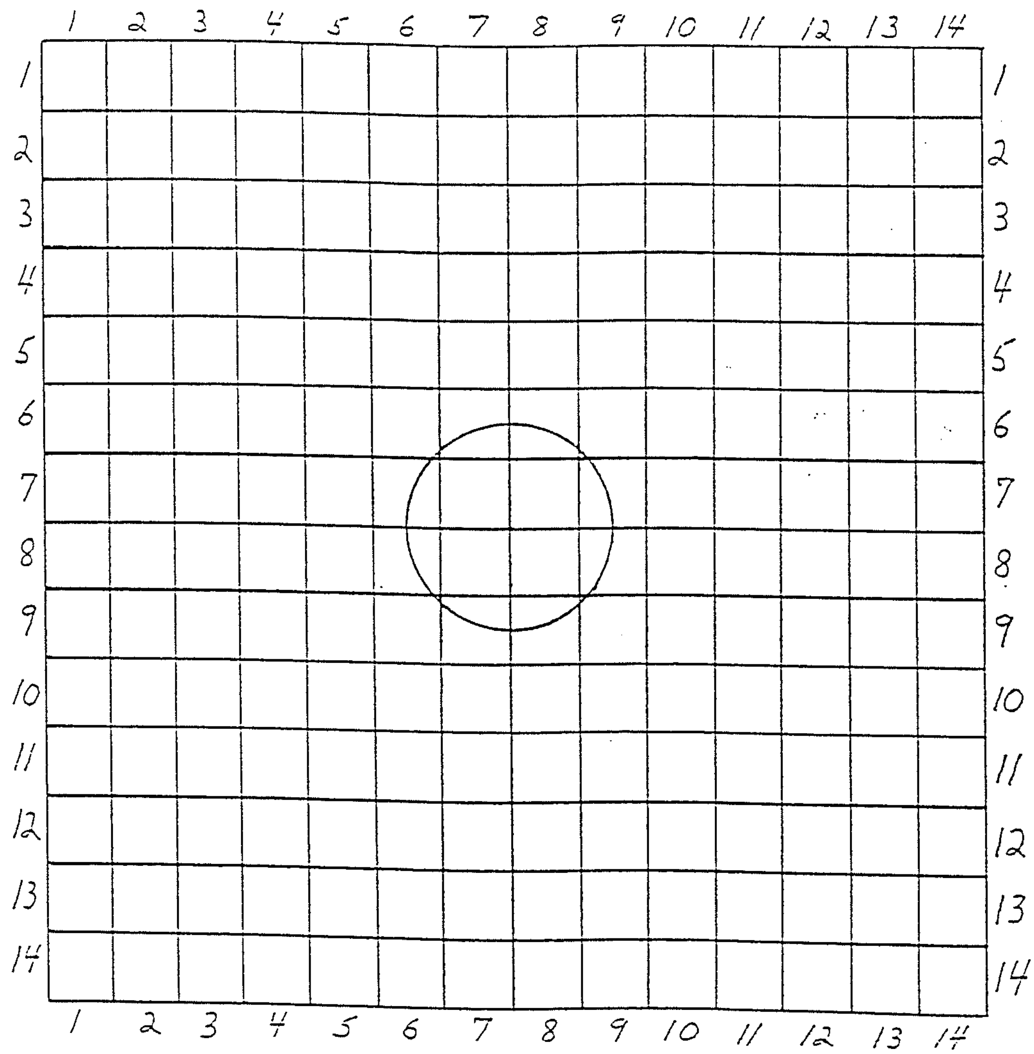
At 183 cm (6 feet) from the target there was a "home spot" from which the golfer began each putt. This ensured that all golfers putted from the same position. The home spot consisted of a round piece of two-sided tape 4.3 cm (1.68 in.) in diameter, with a hole punched in the center. One side of the tape was secured to the carpet, and the other was covered with thin black material so that it would not be detected by the tracking system. The home spot was sufficiently thin so as to provide minimal interference with the motion of both the putter and the ball.

In order to quantitatively assess the position of the golf ball following a putt, a Sony AVC 1400 video camera was located directly above the simulated hole. Output from this camera was displayed on a Sony Video Monitor (CVM 115). Covering the screen of this monitor was a transparency containing a grid for measuring the final position of the ball. The grid divided the field of view into 14 rows, 14 columns, and 1 target region, resulting in 197 critical areas (see Figure 1).

The tracking system consisted of two Panasonic Digital TV cameras (CL-354), connected to a video-acquisition module, that were used to monitor the

Figure Caption

<u>Figure 1</u>. Final position grid.


1 2 3 4 5 6 7 8 9 10 11 12 13 14
1 2 3 4 5 6 7 8 9 10 11 12 13 14

movements of the silver target on the putter head (30 times per second). Both cameras were mounted on a tripod across from the golfer and they were angled downward in order to view the putter. The camera lenses were located 930 cm above the putting carpet and were angled downward at 80 degrees so that their viewpoint was as close to directly above the putter as possible without obstructing the golfer's view. Additionally, since the cameras were separated horizontally by a distance of 28.5 cm, they were mounted with "toe-in" (5 degrees) so as to both point towards the center of the desired field of view.

A Zenith Video Monitor (ZVM-122) was used to directly observe the video output from the TV camera on the golfer's left side. This allowed the experimenter to observe the golfer's club from the same perspective as the tracking system.

An IBM-compatible personal computer (IPC-486) was used to record all data gathered by the cameras, calculate the experimental variables, and give feedback to both the experimenter and participant. The computer recorded the position of the silver target at the end of the putter head 30 times a second as the participant moved through the putting stroke.

Tests of the tracking system in this configuration conducted prior to this study, revealed that it was accurate to approximately +/- .01 cm in both horizontal planes and +/- .02 cm in the vertical plane (Pear, 1997). Further, it was determined that the velocity of any reasonable golf putt was well within the limitations of the system.

In order to aide provision of feedback to the participants in Experiment 2 four diagrams were used to visually illustrate the verbal feedback provided (see Appendix A). One diagram at a time was displayed, and it was secured to the wall of the experimental room (approximately 140 cm away) directly across from the participant.

Experiment 1

Method

Participants

To recruit participants, signs were posted at a local indoor driving range asking volunteers who were low handicap golfers, putted right handed, and did not use an unorthodox style. Ten volunteers were recruited, 9 of whom completed the study. The tenth volunteer completed only half of the study and was therefore dropped from the analysis. Of the 9 participants, 8 were male, ranging in age from 25 to 67 and 1 was a 24-year-old female.

For the initial participant recruitment a low handicap golfer was anyone who had a handicap of 15 strokes or less and played on a regular basis. For the 9 golfers involved in the study, handicaps ranged from 4 to 14 and had a mean of 9.2.

Further, participants were screened both verbally and physically for the use of an unorthodox putting style. An unorthodox putting style included any action that would not normally be taught to a novice golfer, such as a cross-handed grip or a loose-wristed style. Participants were asked whether or not they used an unorthodox style at the time of recruitment. If they indicated that they did not, they were recruited and then physically assessed during several practice putts (see Appendix B). None of the recruited participants used an unorthodox style.

Procedure

As each participant entered the experimental room they were briefed on the setup and procedures. They were then allowed to take 5 to 10 practice trials in order to further familiarize themselves with the procedures, putting equipment, and putting surface. Following this familiarization period, each participant was asked to complete ten 10-trial blocks of putts. Due to the length of this procedure, participants were allowed to complete the task over two sessions of approximately 1 hour each. Four of the participants opted to complete the task during one longer session.

Data collection. During each trial, the participant completed a practice putt, followed by an actual putt. For the practice putt, the participant first placed the ball to the side of the home spot, then aligned the alignment mark on the putter head with both the home spot, and the target. When ready to putt, the golfer said "ready", indicating to the experimenter to begin recording the putt. Following the word "ready" the participant was asked to pause so that data recording could begin. After this brief pause the participant was to make their putting stroke while saying to him/herself some sort of cue words that assisted them, such as "...swing [on the backswing]...smooth [on the putting stroke]". Cue words were based on a participant's preference, however if no preference currently existed, "...swing...smooth" was requested. The movements of the putter, including backswing, home spot contact, and follow-through, were recorded as the participant swung the putter over the home spot as if the ball was actually there. Recording stopped when the club passed out of the field of view of the system, or it was clear to the experimenter that the follow-through was complete.

Following this practice putt, the golfer immediately made an actual putt using the same procedure as above; however, this time the golf ball was used. For the actual putt, the participant first placed the golf ball on the home spot, then aligned the alignment mark on the putter head with both the ball and the target. When ready to putt, the golfer said "ready", indicating to the experimenter to begin recording the putt. Following the word "ready" the participant paused, and then said to him/herself the cue words, such as "...swing...smooth", while swinging the club. The movements of the putter were recorded in the same manner as above.

When the golf ball stopped rolling, its final position was recorded. The experimenter observed the output of the video camera overlooking the target area. Using the final position grid that was placed on the monitor (see Figure 1), the experimenter indicated which of the critical areas the majority of the ball came to rest in. This was accomplished by recording the row and column number of the critical area, and whether or not the ball was "on target". If the ball was not on target the computer used the row and column number data, to calculate and record the ball's approximate distance from the target. The experimenter then reset the system, while the golfer retrieved the golf ball and prepared for the next trial.

On rare occasions the golf ball would fall exactly on a line dividing regions of the final position grid, making it impossible to clearly determine in which neighboring regions the majority of the ball resided. In this instance, or more frequently, when the ball came to rest outside of the grid, the trial was excluded and repeated.

For each putt recorded, the system calculated four main measures: initial clubface angle, swingpath angle, putter velocity, and putter acceleration.

Initial clubface angle was the angle of the club, relative to a straight line from the home spot to the target. This measure was calculated from the data when the club was aligned with the ball but not yet moving.

Swingpath angle was the angle of the forward swing, relative to a straight line from the home spot to the target. This measure was calculated from the line linking the last data point collected prior to ball contact to the first data point collected following ball contact.

Putter velocity was the velocity of the club, as calculated from the last data point collected prior to ball contact to the first data point collected following ball contact.

Putter acceleration was the acceleration of the club, as calculated from the velocity of the club between the penultimate and last data points prior to ball contact and the velocity value calculated above.

Besides these four measures, the system also recorded the final resting position of the ball, whether or not it was "on target", and if not, its distance from the target. As mentioned above, the final position was recorded as a row and column number representing one of the critical regions on the final position grid (see Figure 1).

Since the golf ball was not used for the practice putt, some alterations to the data collection procedures were required. First, for the four main measure calculations, the home spot was used as the contact point. Second, the final resting position of the ball could not of course be calculated for the practice putt.

Data analysis. To determine whether any of the four main variables would be useful predictors of the golf ball's final resting position, a Pearson product-moment correlation coefficient (r_{xy}) matrix was calculated on both individual and group data for each variable. The correlations of greatest interest included both clubface angle and swingpath angle with final resting column, and velocity with final resting row (see Figure 1). A group data correlation coefficient of at least .3 with a two-tailed significance level of at least .001 was required to consider the value a useful predictor. Similar findings for individual participant data was used to strengthen the argument for a predictor variable. For acceleration, the conditional probability of the ball coming to rest within the target area in the center of the grid (see Figure 1) was calculated for positive and negative acceleration at ball contact.

Once some of the above variables were found to be useful predictors, these variables were further analyzed to determine their optimal range. Optimal ranges were calculated from the swingpath angle data corresponding to trials in which the ball came to rest in the target area or the two center columns, and from the velocity data corresponding to trials in which the ball came to rest in the target area or the two center rows, of the final position grid (see Figure 1). Similarly, had the other two variables been useful predictors, optimal ranges would have been calculated from the clubface angle data corresponding to trials in which the ball came to rest in the target area or the two center columns, and from the acceleration data corresponding to trials in which the ball came to rest in the four central regions of the grid.

The optimal ranges were created by taking the data identified above and calculating the mean and variance for each. These values were used along with a critical value (t_{cv}) to create a 95%, two-tailed confidence interval:

$$CI_{95} = x +/- (t_{cv}) (s_x) \quad (1)$$

where:

x = the sample mean

t_{cv} = the critical value from the t-distribution

s_x = the estimated standard error of the mean

Using this confidence interval assured that there was a 95% chance that the true mean was included within the optimal range, and provided an optimal range that was slightly more stringent for training the novice golfer in Experiment 2.

Results

The data collected in Experiment 1 were analyzed to determine whether or not any of the four main variables were useful predictors of the golf ball's final resting position. To analyze clubface angle, swingpath angle, and putter velocity, a correlation coefficient matrix was calculated. A correlation coefficient of at least .3 with a two- tailed significance level of at least .001 was required to consider the value a useful predictor.

Of the four variables examined, putter velocity and swingpath angle were considered useful for inclusion in Experiment 2. The correlation coefficient matrix for the combined participant data revealed a correlation coefficient of $-.3400$ for putter velocity and final resting row, and .3671 for swingpath angle and final resting column ($p < .0001$).

Further analysis of these two main variables on a participant-by-participant basis, revealed a correlation coefficient range of $-.3525$ to $-.6930$ for putter velocity and final resting row, with all nine participants meeting the $r \geq .3$ criterion at the $p < .001$ level. Similarly, the correlation coefficient range for swingpath angle and final resting column for the individual participants was between .0342 and .4889 with three of the nine participants meeting the $r \geq .3$ criterion at the $p < .001$ level.

Clubface angle did not meet criteria for inclusion in Experiment 2 because of a low combined participant correlation coefficient. However, it should be noted that a participant-by-participant analysis revealed a range of -.0143 to .4010 for clubface angle and final resting column, with two of the nine participants meeting criteria ($r \geq .3$, $p < .001$). As one might expect, it should also be noted that there was a significant correlation between the initial clubface angle and swingpath angle. The correlation coefficient matrix for the combined participant data revealed a correlation coefficient of -.1400 ($p < .001$). The participant-by-participant correlations ranged from .0640 to .5319 with six of the nine participants meeting the $r \geq .3$ criterion at the $p < .001$ level.

The last main variable was putter acceleration, since its analysis was not amenable to a correlation coefficient matrix, a visual analysis and a comparison of conditional probabilities were conducted. This analysis revealed that the low handicap golfers were attempting to accelerate through the ball contact point. The acceleration value for actual putts was positive for 854 of the 900 putts (94.89 %). Similarly, of the 130 actual putts that landed on the target, 118 of these had a positive acceleration value

(90.77 %). However, when looking at the conditional probabilities, it was found that positive acceleration was actually less likely to lead to target hits. For putts with positive acceleration only 118 of the 854 putts landed on target ($p = .1382$), whereas for negative acceleration 12 of 46 hit the mark ($p = .2609$). Consequently, although the low handicap golfers were usually still accelerating at the point of ball contact it appears that their odds of landing on the target were almost twice as good when they were decelerating.

Since both putter velocity and swingpath angle appeared to have some relation to the final resting position of the golf ball, these variables were further analyzed to determine their optimal range. The optimal ranges were calculated from the swingpath angle data that was classified as having fallen into the target area plus the two center columns, and from the velocity data that was classified as having fallen into the target area plus the two center rows, of the final position grid. The optimal ranges were created by calculating a 95%, two-tailed confidence interval on the target hit data for both of the variables. The optimal training range for putter velocity was 79.55 to 81.24 cm/sec. (M = 80.39 cm/s, SD = 6.82 cm/s), and for swingpath angle was -4.54 to -3.95 degrees (M = -4.25 deg, SD = 2.79 deg).

Discussion

The main goal of Experiment 1, was to conduct a general test of the tracking system's ability to accurately record useful data on the putting stroke of several low handicap golfers.

In terms of accuracy, the system is inferior to the laser system developed by McGlynn et al. (1990); however the laser system was only capable of assessing a clubface angle and did not record any movement of the putter. The participants in the McGlynn et al. study completed a putt following the alignment task; however no data was collected on this portion of the skill. The current system was not only capable of duplicating this initial alignment measure, but was also used to assess the entire putting stroke as well. The position of the silver target at the end of the putter head was recorded three dimensionally at 30 times per second. This assessment allowed the calculation of putter velocity, putter acceleration, and swingpath angle at ball contact, as well as clubface angle prior to the swing. It should be noted that the precision of the current system can be improved by using cameras with higher resolution and faster scan rates.

Four main variables were selected for analysis in Experiment 1. Two of the variables, putter velocity and swingpath angle, met the required criteria to be considered useful predictors of the golf ball's final resting position. These predictors were further analysed to determine their optimal range for use in Experiment 2. The fact that the system was capable of determining these predictors is testament to its applicability to research into the golf putt or similar actions.

The group findings on putter velocity and swingpath angle, were strengthened by the participant-by-participant correlation coefficient analysis. The link between putter velocity and the golf ball's final resting row was so strong that all nine participants met the required criteria. Although not as strongly, the link between swingpath angle and the golf ball's final resting column was also strengthened by the fact that three of the nine participants met the criteria.

One reason for the slightly weaker correlation than that found for putter velocity, is the possibility of interference from another main variable, clubface angle. This variable did not meet the inclusion criteria, but was still significantly related to swingpath angle.

It is possible that a participant with a correct swingpath angle had a poor outcome because of an incorrect clubface angle. Similarly, an incorrect swingpath angle could have resulted in a errantly good outcome because of an incorrect, but opposite clubface angle. For example, if a poor swingpath angle would send the ball to the right of the target and a poor clubface angle would send the ball to the left of the target, the resultant putt may actually be fairly close to the target.

Turning to clubface angle, this variable may not have reached significance because of the above mentioned correlation with swingpath angle. Further, the correlation data for both swingpath angle and clubface angle may have been weaker than that of the putter velocity data, simply because there was more variability in the putter velocity data than in the angular data.

A second reason why clubface angle may not have reached significance may be that initial alignment, prior to the swing, is less critical for determining the final resting position of the ball, than the clubface angle at ball contact. Unfortunately, the system was unable to make such a measurement; however, future versions of the system that may be able to track multiple points would have this capability.

Currently, there are systems available that can track several points on a person's body (Gorant, 1998). However, these are video systems that have to be downloaded into a computer for later analysis. The advantage of the computer tracking system remains its ability to provide immediate feedback. This is the type of feedback required for altering abilities through behavioral techniques.

The analysis of the main variable of acceleration revealed that the low handicap golfers were definitely attempting to accelerate at the time of ball contact. Positive acceleration was an expected finding because the popular literature on putting suggested that positive acceleration at contact was desirable, and subsequently, the instructions originally provided to the participants requested it. However, the present results indicate that negative acceleration is almost twice as likely to lead to the golf ball stopping on the target.

This finding is contrary to the both the literature, and popular belief on putting. Although they were not requested, one possible reason for the negatively accelerated putts, was the fact that the golfers in this study were required to putt the golf ball in such a way as to have it come to rest on the target. This is unusual in that putts with too high of a velocity would not land on the target, even though they would have dropped into the hole on a conventional putting surface. The rarity of the negatively accelerated putts, suggests that the low handicap golfers did not decelerate their putting strokes to account for this change in procedure.

Given the relatively small sample size, and the fact that only one of every four negatively accelerated putts actually landed on the target, the experimenter was reluctant to suggest such a drastic change in putting style to the novice golfers in Experiment 2. However, future studies investigating the merits of both acceleration and deceleration at ball contact are suggested. These studies are needed to determine whether this finding is simply an anomaly or a breakthrough in putting technique.

Finally, the comparisons made for all of the main variables in relation to the target, were dependent upon the final position grid. The grid was an attempt to quantify the golf ball's final resting position without having to take the time to repeatedly measure it by hand. The grid functioned well, but future studies might benefit from a less crude measure.

In general, this experiment succeeded in showing the system's capability of collecting useful data on the putting stroke of low handicap golfers. Although less accurate than a laser, the system's added flexibility allowed for successful calculation of four main variables associated with the golf putt and further comparison to the putting outcome. Two of the main variables (putter velocity, swingpath angle) met the criteria for inclusion in Experiment 2 and were further analysed to determine their optimal ranges. Of the two main variables that did not meet criteria for inclusion in Experiment 2, it was determined that clubface angle might have been better measured at a different point in the swing; and while accelerating at ball contact is common, it was not necessarily related to the outcome. Further study is required to more fully understand the links between these variables and the golf ball's final resting position.

Experiment 2

Method

Participants

Signs were posted around the University of Manitoba campus asking for volunteers who were novice golfers, putted right handed, and did not consider themselves to be expert miniature golfers. A novice golfer was anyone who had played golf at least 5 times, but fewer than 15 times. Two volunteers were recruited and both completed the study. The first participant was a 26 year old male and the second, a 30 year old female.

Basic skills training. Prior to participating in the experiment, both participants were trained on proper putting technique. This training consisted of

10 basic skills such as proper grip, stance, alignment, and swingpath. The proper technique on each of these variables was derived from the experimenter's experiences taking lessons from a local golf pro, and from consultation with another graduate student who was also completing a study that involved assessing the form of a golf putt. The experimenter conducted the training by teaching each of the 10 basic skills separately before combining them to create the entire putting process.

Training on each of the skills consisted of a verbal description and demonstration of the proper technique, followed by a brief session of participant practice and critique by the experimenter. After each of the 10 basic skills was mastered on an individual basis, the skills were combined to create a correct putting stroke. Training was completed with the participant making several complete putts while the experimenter critiqued any errors in the basic skills.

Once the participant was comfortable with the skill, he/she was physically assessed during several practice putts (see Appendix B). The assessment consisted of a checksheet in which it was required that the participant demonstrate correct form in all 10 basic skills at least three times during the course of several complete putts. Approximately 10 putts were required because the experimenter could observe only about half of the basic skills during any given putting stroke. In the event of an error the participant was corrected and the training repeated. (If repeated training was unsuccessful the participant was to be given credit for their participation to that point and excluded from the study. This step was not necessary, as both participants were successfully trained on the first attempt.)

Procedure

This experiment tested the effectiveness on the actual putt of feedback on the practice putt. This was accomplished by using an ABACA design where scores with two different types of feedback were compared to scores without feedback. In this experimental design, the A phases corresponded to baseline conditions, the B phase corresponded to the first treatment, and the C phase corresponded to the second treatment (see Table 1).

The first time each participant entered the experimental room he/she was briefed on the setup and

Table 1

Conditions Experienced by Participants in Each Phase of Experiment 2

	Phase	Condition	No. of Sessions
Participant 1	A	Baseline	5
	B	Putter Velocity Training	16
	A	Return-to-Baseline	5
	C	Swingpath Angle Training	25
	A	Return-to-Baseline	5
Participant 2	A	Baseline	5
	B	Swingpath Angle Training	13
	A	Return-to-Baseline	5
	C	Putter Velocity Training	26
	A	Return-to-Baseline	7

every time after that reminded of the procedures. Once briefed, participants took 5 to 10 practice trials in order to further familiarize themselves with the procedures, putting equipment, and putting surface.

Baseline. Following the familiarization period, each participant started the study in the baseline condition. The baseline condition was identical to the condition used to gather the data in Experiment 1 except for the number of 10-trial blocks of putts completed. In Experiment 1 participants were required to complete ten 10-trial blocks of putts. In Experiment 2 participants were required to complete a minimum of five 10-trial blocks of putts. However, when the experimenter examined the percentage of putts on target for each 10-trial block, if stable responding had not occurred the participant remained in the baseline phase until such time that it did. Putts were considered "on target" when the ball stopped in the center critical region of the final position grid (see Figure 1). For each 10-trial block of putts, the percentage of putts on which the ball fell into each critical region was calculated. Performance was considered stable when the range in the percentage of putts on target was 10% or less for three consecutive 10-trial blocks and the percentage of putts on target did not show an upward trend. Due to the potential length of this procedure, participants were required to complete the task over two or more sessions of approximately 1 hour each.

Using the same protocol as in Experiment 1, each trial consisted of two putting strokes. The first stroke was a practice putt, in which the participant swung the putter over the home spot without the golf ball in place. The second stroke was an actual putt, where the golfer used the ball, both for putter alignment and the putting stroke itself. When the golf ball stopped rolling, its final position was recorded using the video monitor and final position grid (see Figure 1). The experimenter then reset the system, while the golfer retrieved the golf ball and prepared for the next trial.

Treatment. Once stable responding had been observed in baseline, the participant was introduced to the treatment. The treatment phase consisted of a minimum of five 10-trial blocks of putts, with the same requirements of stable performance as during baseline.

Due to the potential length of this procedure, participants were required to complete the task over several sessions of approximately 1 hour each.

As in baseline, each trial consisted of a practice putt followed by an actual putt. However, the difference between baseline and treatment was that the participant now received feedback on the accuracy of the practice putt, without the golf ball, prior to the actual putt using the golf ball. By doing so, it was hoped that the participant would be able to correct any errors detected and thereby make the necessary adjustments prior to making the actual putt.

Once the participant completed the practice putt, the system analyzed the data collected, and the values reported were compared to optimal ranges calculated in Experiment 1 (see Equation 1). If the current value fell within the optimal range, positive verbal and visual feedback was provided. However, if the current value fell outside of the optimal range negative verbal and visual feedback was given. After receiving this feedback, the actual putt was performed using the same procedures as in baseline.

The feedback that the participant received varied slightly, depending on which of the main variables was being modified at the time. The results of Experiment 1 dictated that two of the four variables were to be trained. Since two variables in Experiment 1 were found to be useful predictors of the golf ball's final resting position, Experiment 2 became an ABACA design. As there was no protocol in the literature indicating an optimal training order, the first participant was trained first on putter velocity then swingpath angle, while the second participant was trained in the reverse order. This was done in order to counterbalance for a possible order effect.

At the beginning of every training session, the experimenter verbally explained to the participant exactly which variable feedback was being provided for, and the two types of feedback that would be provided. The general feedback form consisted of a verbal, three-point Likert scale ranging from "too little" to "too much". In the two trained cases, a practice swing that produced datum within the given optimal range, resulted in positive verbal feedback such as: "nice swingpath", "perfect weight", etc. For training on the swingpath angle, the negative verbal feedback consisted of "too far to the right" or "too far to the left" (of the hole). In the case of putter velocity, the feedback was "too hard" or "too soft".

Besides the verbal feedback provided by the experimenter, the participant was also able to look at one of four diagrams (see Appendix A) that demonstrated each of the three verbal prompts in a visual format. The diagram related to the main variable being trained was posted on the wall of the experimental room, directly in front of the golfer. This procedure was used to help ensure that the golfer clearly understood the meaning of the verbal feedback being provided.

Return-to-baseline. Once stable responding had been observed in treatment, the participant was returned to the baseline condition. Return-to-baseline consisted of a minimum of five 10-trial blocks of putts, with the same requirements of stable performance as during the previous phases. Due to the potential length of this procedure, participants were required to complete the task over two or more sessions of approximately 1 hour each.

In the return-to-baseline phase, each trial still consisted of a practice putt followed by an actual putt. However, as in the first baseline phase, the participant no longer received feedback on the accuracy of the practice putt.

Final two phases. Following the return-to-baseline phase the participant was returned to the treatment phase; however, this time they received feedback based on the second treatment variable. Finally, the participant was again returned to the baseline condition to complete the study.

Data collection. Data collection in all five phases of Experiment 2 was identical to that of Experiment 1.

Data analysis. The data collected in Experiment 2 were analyzed to determine whether or not the feedback provided on the practice putts had any effect on the actual putts. It was hypothesized that the participants would not differentiate between the practice and actual putts, treating each simply as a putt. Consequently, feedback provided on the practice putt should have had the largest effect on the actual putt that followed. The data analysis began with an investigation into the effects of treatment on the actual putts, specifically looking at whether or not the participants improved their ability to get the golf ball to the target. Comparisons were made between phases for the percentage of actual putts that landed on target, on weight, and on line.

A putt was considered "on target" if the golf ball came to rest within the center target of the final position grid (see Figure 1). A putt was considered "on weight" if the golf ball came to rest within the center target, or within the two middle rows of the final position grid. This additional analysis allowed an assessment of putter velocity that was independent of the swingpath angle. In the same fashion, a putt was considered "on line" if the golf ball came to rest within the center target, or within the two middle columns of the final position grid. This analysis allowed an assessment of swingpath angle that was independent of the putter velocity.

The data analysis then proceeded to examine the effect of treatment on the target variables themselves. For both practice and actual swings, mean putter velocities and swingpath angles were compared with their respective baseline and return-to-baseline phases.

For each participant, the above analyses began with a visual inspection of the data to determine whether or not there were any obvious effect or interesting patterns to the data. Following the visual analysis, several least significant difference (LSD) tests were conducted comparing practice and actual putt performance between the baseline and treatment, and treatment and return-to-baseline phases.

In terms of the data analysis, the purpose of this statistical test is simply to support the findings of the visual analyses. However, given the design of this experiment caution needs to be exercised before relying too heavily on the statistical results. When using the LSD test, an assumption is made with respect to the independence of the data points. In this experiment the independence of the data points is questionable because the data is coming from single subjects who are learning a new skill. Consequently, each data point is somewhat dependent on the previously learned skills and earlier data. For all tests, a critical value of .05 was required for significance.

Results

The data collected in Experiment 2 were analyzed to determine whether or not the feedback provided on the practice putts had any effect on the actual putts.

Participant 1

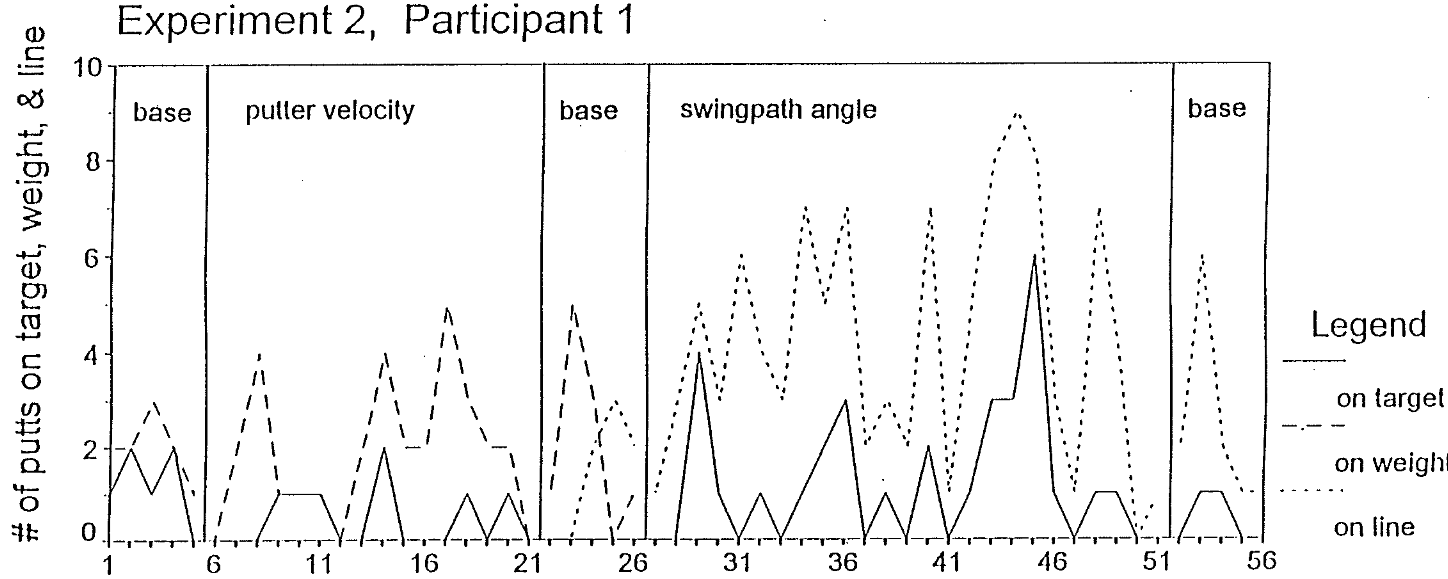
On target, on weight, and on line performance. The visual analysis revealed that the Participant 1 had a general decrease in the number of putts on target, but an increase in the number of putts on weight from baseline to putter velocity training (see Figure 2). Further, these trends continued for both variables during the return-to-baseline phase, with the number of putts on target dropping to zero and the number of putts on weight continuing to increase. Both the number of putts on target, and on line, increased from the first return-to-baseline phase to the swingpath angle training phase, and then decreased during the final return-to-baseline phase. It should be noted that this participant scored as many as 6 out of 10 putts on target, and as many as 9 out of 10 putts on line, during the swingpath angle training phase. This is compared to an average of zero putts on target, and 1.40 out of 10 putts on line, during the previous

Figure Caption

Figure 2. Number of putts on target, on weight, and on line per block for Experiment 2, Participant 1.

Number of putts on target, on weight, and on line per block

Experiment 2, Participant 1



Blocks of 10 putts

base: baseline, putter velocity: putter velocity training

swingpath angle: swingpath angle training baseline phase.

Computation of means helped confirm the above noted patterns. In baseline, Participant 1 scored means of 1.20 putts on target and 1.80 putts on weight (see Table 2). During putter velocity training there was a decrease in the mean number of putts on target, but a slight increase in the mean number of putts on weight. In the first return-to-baseline phase there were no putts on target, but the number of putts on weight remained almost the same as in the previous phase. Also in this phase, Participant 1 scored a mean of 1.40 putts on line. During swingpath angle training there was an increase in both the mean number of putts on target and the mean number of putts on line, and in the final return-to-baseline phase, there was a decrease for both variables.

Least significant difference (LSD) tests were conducted comparing the on target, on weight, and on line putting performance in the baseline versus treatment, and treatment versus return-to-baseline phases. For on weight performance the LSD tests failed to reach significance. However, for on target and on line performance, the LSD tests ($p < .05$) revealed

Table 2

Mean Number of Putts On Target, On Weight, and On Line per Phase for Participant 1

	On Target		On Weight		On Line	
	Mean	SD	Mean	SD	Mean	SD
Base	1.20	.84	1.80	.84	--	--
P.V.	.44	.63	1.94	1.48	--	--
Base	0	0	2.00	2.00	1.40	1.34
S.A.	1.24	1.54	--	--	4.20	2.61
Base	.40	.55	--	--	2.40	2.07

Base: baseline, P.V.: putter velocity training, S.A.: swingpath angle training

significant differences between swingpath angle training and the prior baseline phase.

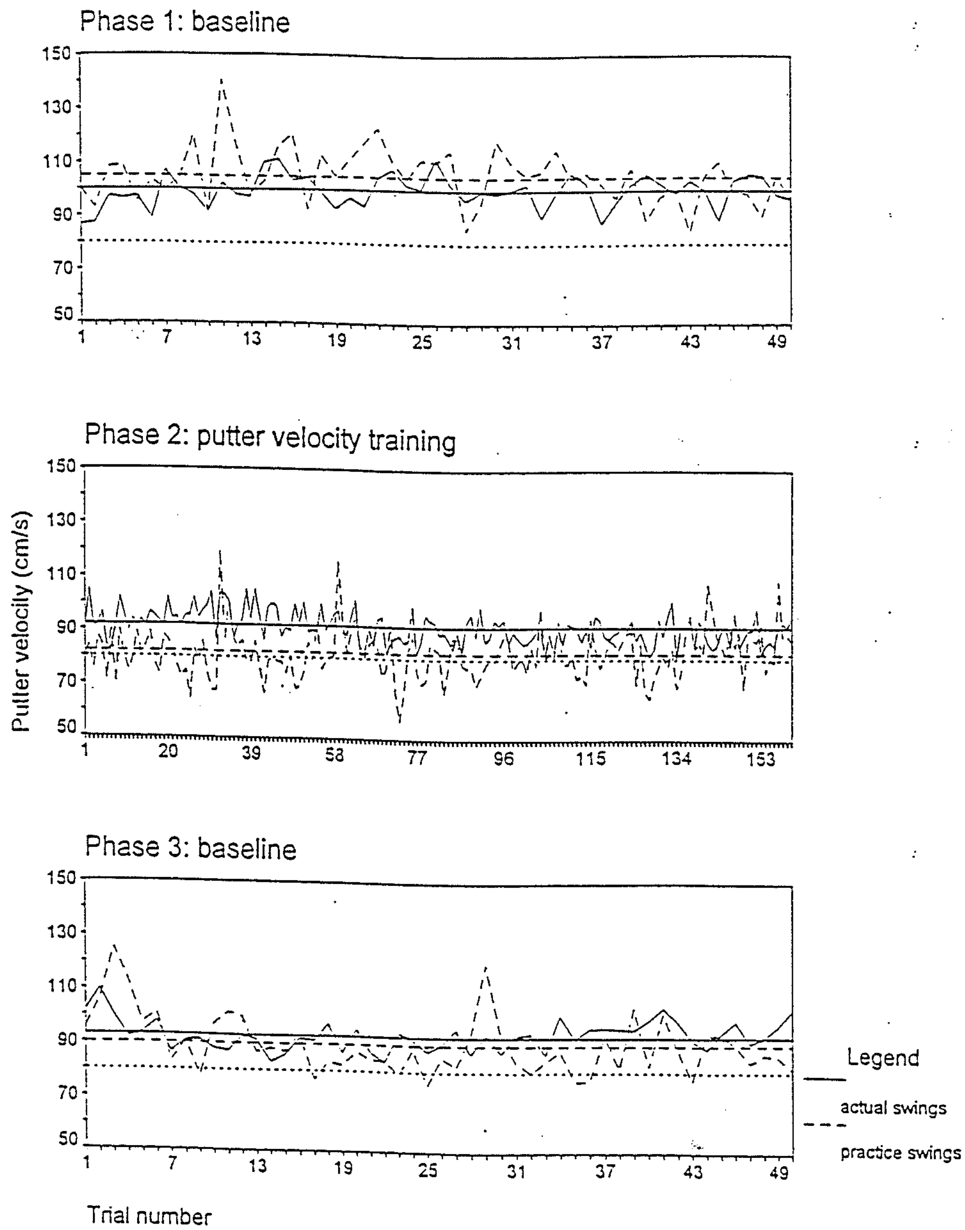
Practice and actual swing performance as a function of putter velocity training. Further analysis revealed that the putter velocities of both the practice and actual putts in the first baseline phase were fairly similar and rather high, with the mean for the practice putts being slightly higher (M = 105.42 cm/s, SD = 10.59 cm/s) than that of the actual putts (M = 99.73 cm/s, SD = 6.11 cm/s) (see Figure 3). During the putter velocity training phase there was a reversal of the mean velocities of the practice and actual putts. The velocity of the practice putts immediately dropped to match the mean training value of 80.39 cm/s and then remained near that level (M = 81.90 cm/s, SD = 9.27 cm/s). The velocity for the actual putts also showed an immediate drop and a slight downward trend during training, but the mean of this variable did not enter the optimal range of 79.55 to 81.24 cm/s (M = 91.73, SD = 5.72 cm/s). During the return-to-baseline phase the velocity for the practice putts increased from the training values, but still remained lower than the velocity for the actual putts which also increased slightly (M_p = 89.91 cm/s, SD_p = 10.93 cm/s, M_a = 93.47 cm/s, SD_a = 5.62 cm/s). Both means remained closer to the optimal range than in the first baseline phase.

Recalling that the participants were asked to complete several 10-trial blocks of putts in each

Figure Caption

Figure 3. Putter velocity of practice and actual swings per trial during phases 1-3 for Experiment 2, Participant 1.

Putter velocity per trial: Experiment 2, Participant 1



Solid and dashed reference lines denote mean values per phase

Dotted reference line denotes mean training value used during phase 2

phase, the graph of the mean putter velocity of the practice and actual swings per block helps to summarize some of the above findings. Figure 4 clearly shows the immediate drop in both velocities during the training phase. It also shows how the velocity of practice putts hovered around the mean training value until the end of the phase, while the velocities of actual swings showed a slight downward trend during velocity training.

LSD tests were conducted comparing both practice and actual putter velocity across the first three phases; baseline versus putter velocity training, and putter velocity training versus return-to-baseline. These tests revealed significant differences ($p < .05$) between both comparisons for practice swings, and between baseline and training for actual swings.

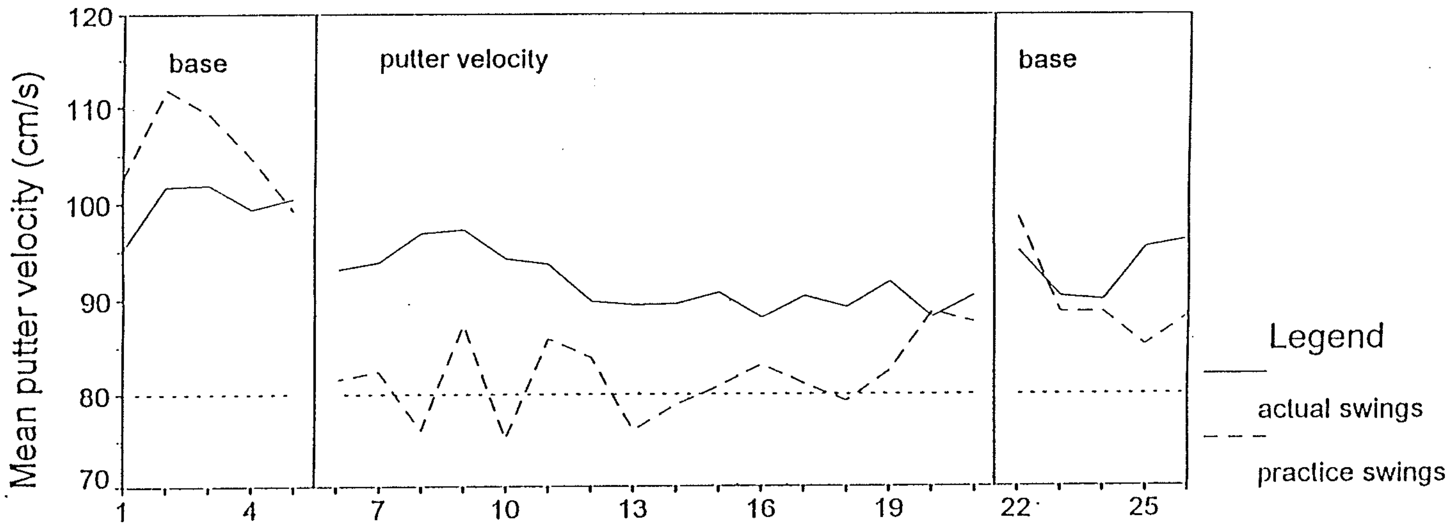
<u>Practice and actual swing performance as a function of swingpath angle training</u>. Turning to swingpath angle training for Participant 1, analysis revealed that the practice and actual swingpath angles during the second baseline phase were quite different from each other. The mean swingpath angle for the practice swings was very close to zero (M = -0.75 deg,

Figure Caption

Figure 4. Mean putter velocity of practice and actual swings per block during phases 1-3 for Experiment 2, Participant 1.

Mean putter velocity per block

Experiment 2, Participant 1, Phases 1 - 3



Blocks of 10 trials

base: baseline, putter velocity: putter velocity training

Dotted reference line denotes mean putter velocity training value

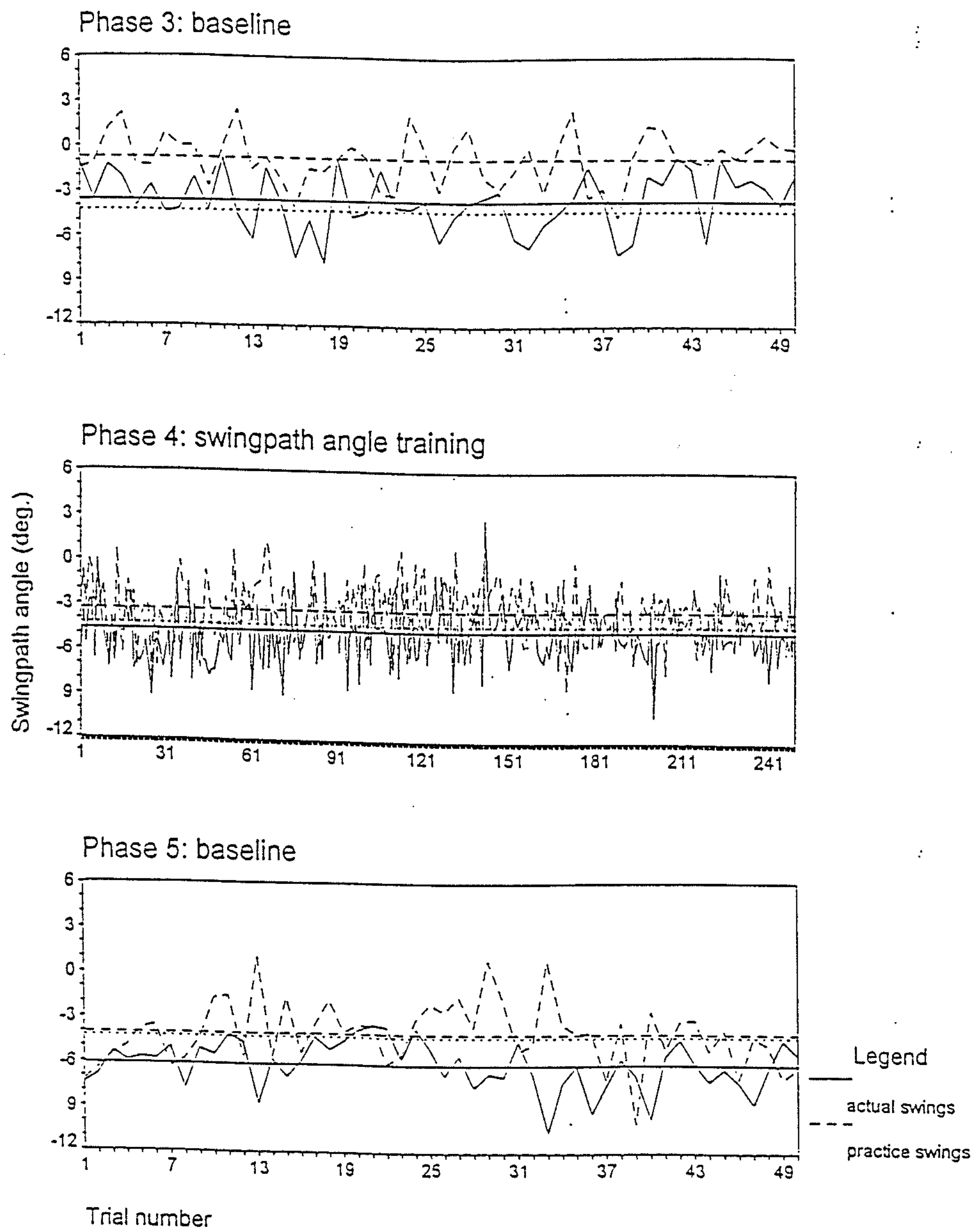
SD = 1.70 deg) while the mean for actual swings was closer to the mean training value that would be used in the next phase (M = -3.59 deg, SD = 1.94 deg) (see Figure 5). During the swingpath angle training phase, the mean swingpath angle for the practice putts (M = -3.30 deg, SD = 1.85 deg) got considerably closer to the mean training value of -4.25 degrees. The mean swingpath angle for the actual putts remained about the same distance from the optimal training value, but this time on the other side (M = -4.65 deg, SD = 1.93 deg). During the final return-to-baseline phase the mean swingpath angle for the practice putts fell inside the optimal range of -3.95 degrees to -4.54 degrees (M = -4.04 deg, SD = 2.20 deg) while the mean angle for the actual putts got farther away from the optimal training value than in either of the previous two phases (M = -6.10 deg, SD = 1.60 deg).

The graph of the mean swingpath angle of the practice and actual swings per block (see Figure 6) clearly shows the immediate change in both swingpath angles at the beginning of the training phase, the increase in the angle of the actual swings in the final phase, and how the angles of the practice and actual

Figure Caption

Figure 5. Swingpath angle of practice and actual swings per trial during phases 3-5 for Experiment 2, Participant 1.

Swingpath angle per trial: Experiment 2, Participant 1



Solid and dashed reference lines denote mean values per phase

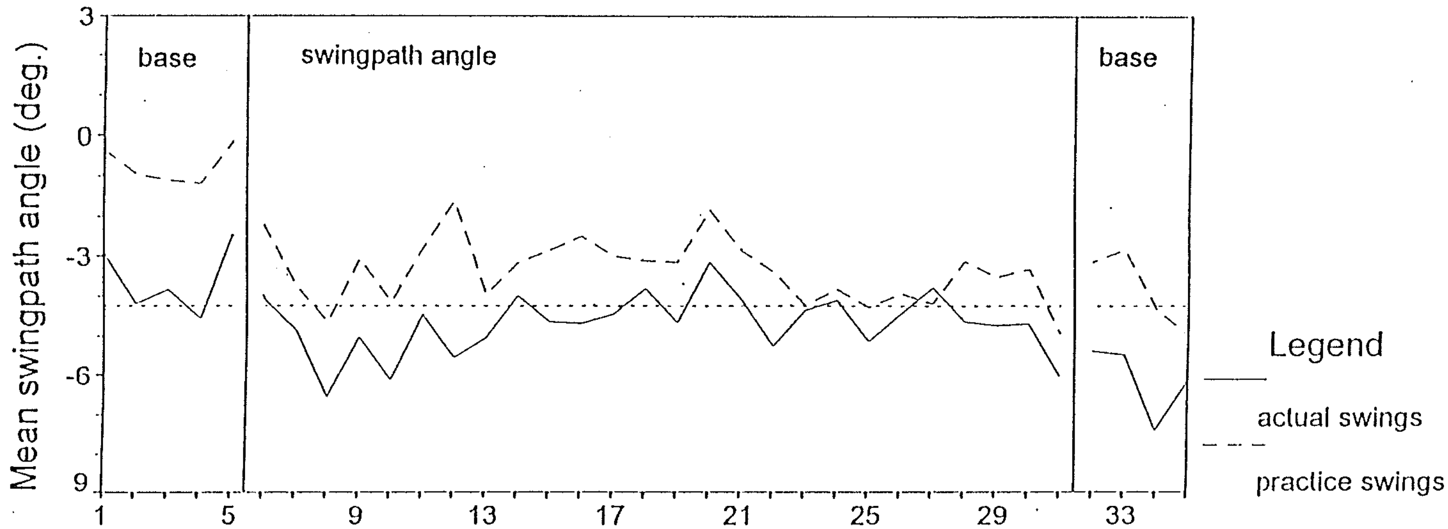
Dotted reference line denotes mean training value used during phase 4

Figure Caption

Figure 6. Mean swingpath angle of practice and actual swings per block during phases 3-5 for Experiment 2, Participant 1.

Mean swingpath angle per block

Experiment 2, Participant 1, Phases 3 - 5



Blocks of 10 trials

base: baseline, swingpath angle: swingpath angle training

Dotted reference line denotes mean swingpath angle training value.

swings often moved together.

LSD tests were conducted comparing both practice and actual swingpath angles across the final three phases; first return-to-baseline versus swingpath angle training, and swingpath angle training versus the final return-to-baseline. These tests revealed significant differences ($p < .05$) in all the comparisons for both practice and actual swings.

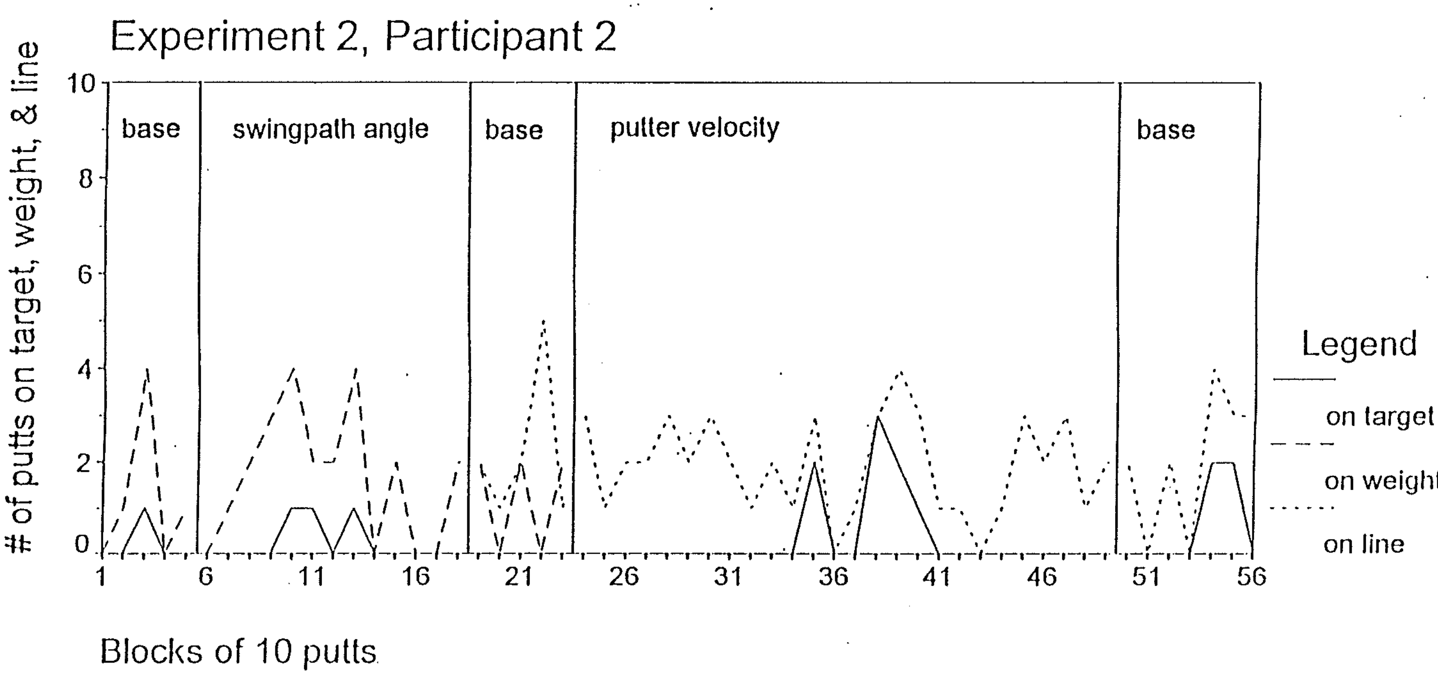
Participant 2

On target, on weight, and on line performance. The visual analysis revealed that there was little change in the number of putts on target, but a slight increase in the number of putts on line from baseline to swingpath angle training (see Figure 7). Further, there was a slight decrease in both variables during the return-to-baseline phase. The number of putts on target increased from the first return-to-baseline phase to the putter velocity training phase, and then continued to increase during the final return-to-baseline phase. The number of putts on weight decreased from the first return-to-baseline phase to the putter velocity training phase and then changed very little in the final return-to-baseline phase.

Figure Caption

Figure 7. Number of putts on target, on weight, and on line per block for Experiment 2, Participant 2.

Number of putts on target, on weight, and on line per block



base: baseline, swingpath angle: swingpath angle training

putter velocity: putter velocity training

Computation of means helped confirm the above noted patterns because in baseline Participant 2 scored means of 0.20 putts on target and 1.20 putts on line (see Table 3). During swingpath angle training there was little change in the number of putts on target, but a slight increase in the number of putts on line. In the first return-to-baseline phase there were no putts on target, but a slight decrease in the number of putts on line. Also in this phase, Participant 2 scored a mean of 2.20 putts on weight. During putter velocity training there was an increase in the mean number of putts on target, but a decrease in the number of putts on weight. In the final return-to-baseline phase, the number of putts on target continued to increase and the number of putts on weight increased marginally.

Least significant difference (LSD) tests were conducted comparing the on target, on weight, and on line putting performance in the baseline versus treatment, and the treatment versus return-to-baseline phases. However, no significant results were found.

<u>Practice and actual swing performance as a function of swingpath angle training</u>. Further analysis revealed that the swingpath angles of both the

Table 3

Mean Number of Putts On Target, On Weight, and On Line per Phase for Participant 2

	On Target		On Weight		On Line	
	Mean	SD	Mean	SD	Mean	SD
Base	.20	.45	--	--	1.20	1.64
S.A.	.23	.44	--	--	1.69	1.44
Base	0	0	2.20	1.64	1.20	1.10
P.V.	.31	.79	1.92	1.06	--	--
Base	.57	.98	2.00	1.53	--	--

Base: baseline, S.A.: swingpath angle training

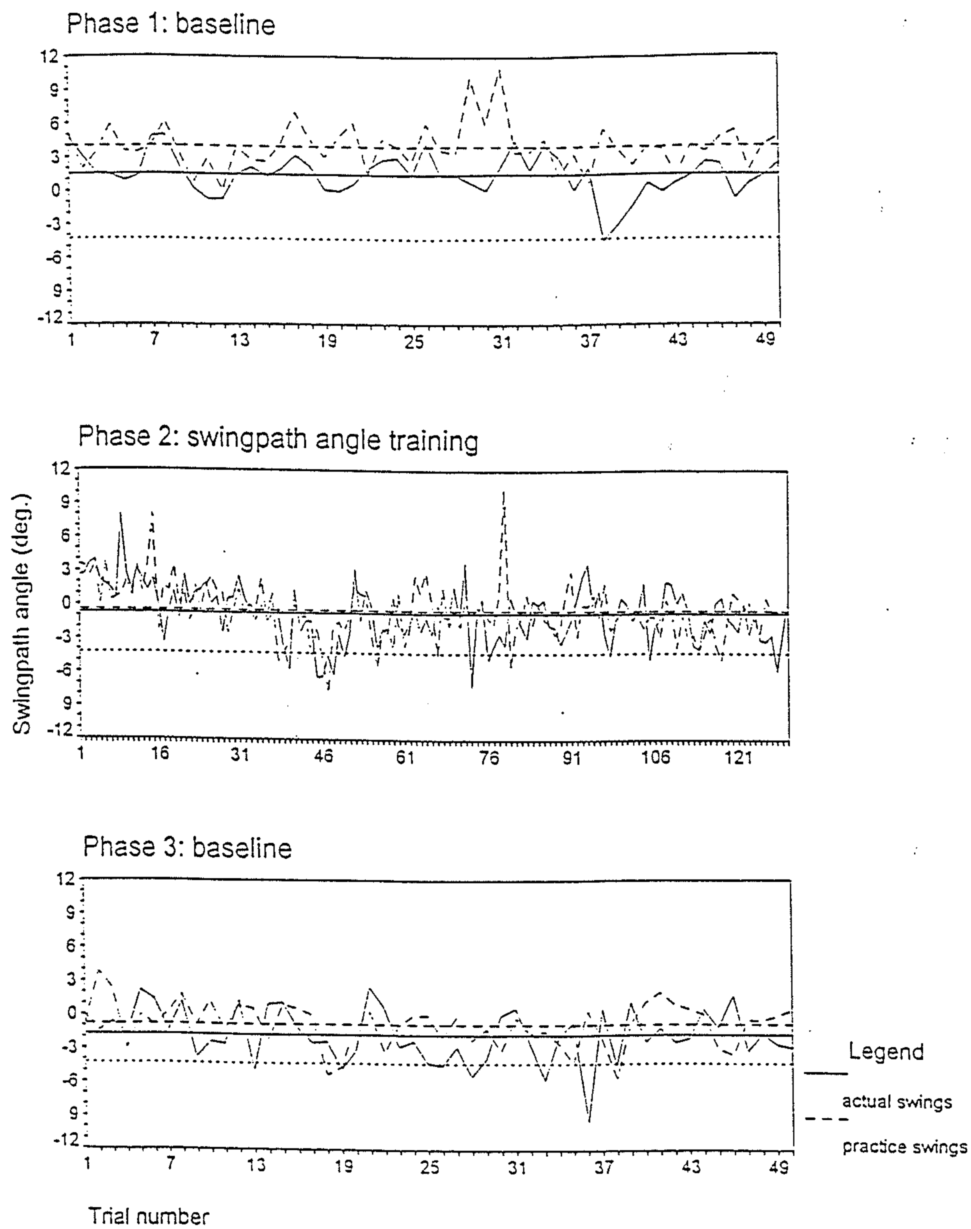
P.V.: putter velocity training

practice (M = 4.02 deg, SD = 2.05 deg) and actual putts (M = 1.53 deg, SD = 1.86 deg) in the first baseline phase were somewhat similar, but very far from the mean training value that would be used in the next phase (M = -3.59 deg, SD = 1.94 deg) (see Figure 8). During the

Figure Caption

Figure 8. Swingpath angle of practice and actual swings per trial during phases 1-3 for Experiment 2, Participant 2.

Swingpath angle per trial: Experiment 2, Participant 2



Solid and dashed reference lines denote mean values per phase

Dotted reference line denotes mean training value used during phase 2

swingpath angle training phase the means for both practice and actual putts were much closer to each other and closer to the mean training value (M_p = −0.46 deg, SD_p = 2.53 deg, M_a = −0.72 deg, SD_a = 2.52 deg), but did not enter the optimal training range of −3.95 degrees to −4.54 degrees. During the first third of this phase both the practice and actual putts showed a steady trend towards the mean training range, but then reversed their direction and tended to hover around the zero degree mark. During the return-to-baseline phase both the practice (M = −0.78 deg, SD = 1.96 deg) and actual putts (M = −1.71 deg, SD = 2.40 deg) remained nearer to the zero degree mark, but did get slightly closer to the mean training value from the previous phase.

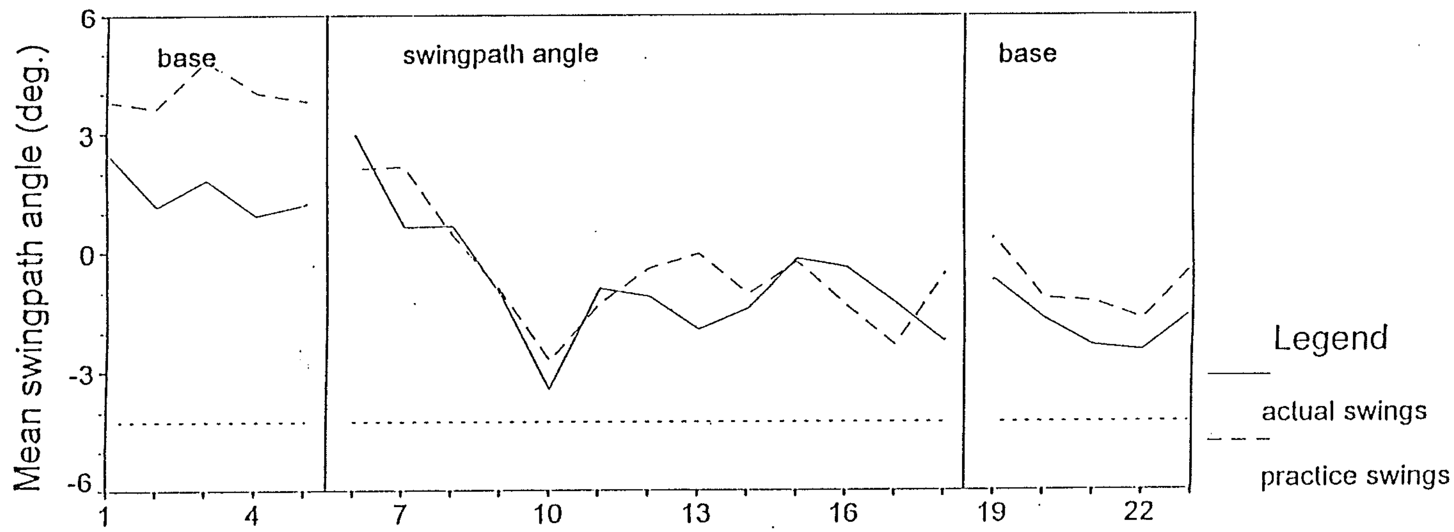
The graph of the mean swingpath angle of the practice and actual swings per block helps to summarize some of the above mentioned findings. Figure 9 clearly shows how the swingpath angles changed from approximately plus three degrees to nearly minus three degrees, but then reversed direction and remained at roughly the minus one degree mark. It also shows that the separation between the mean swingpath angle for

Figure Caption

Figure 9. Mean swingpath angle of practice and actual swings per block during phases 1-3 for Experiment 2, Participant 2.

Mean swingpath angle per block

Experiment 2, Participant 2, Phases 1 - 3



Blocks of 10 trials

base: baseline, swingpath angle: swingpath angle training

Dotted reference line denotes mean swingpath angle training value practice and actual swings was dramatically reduced after the training phase started.

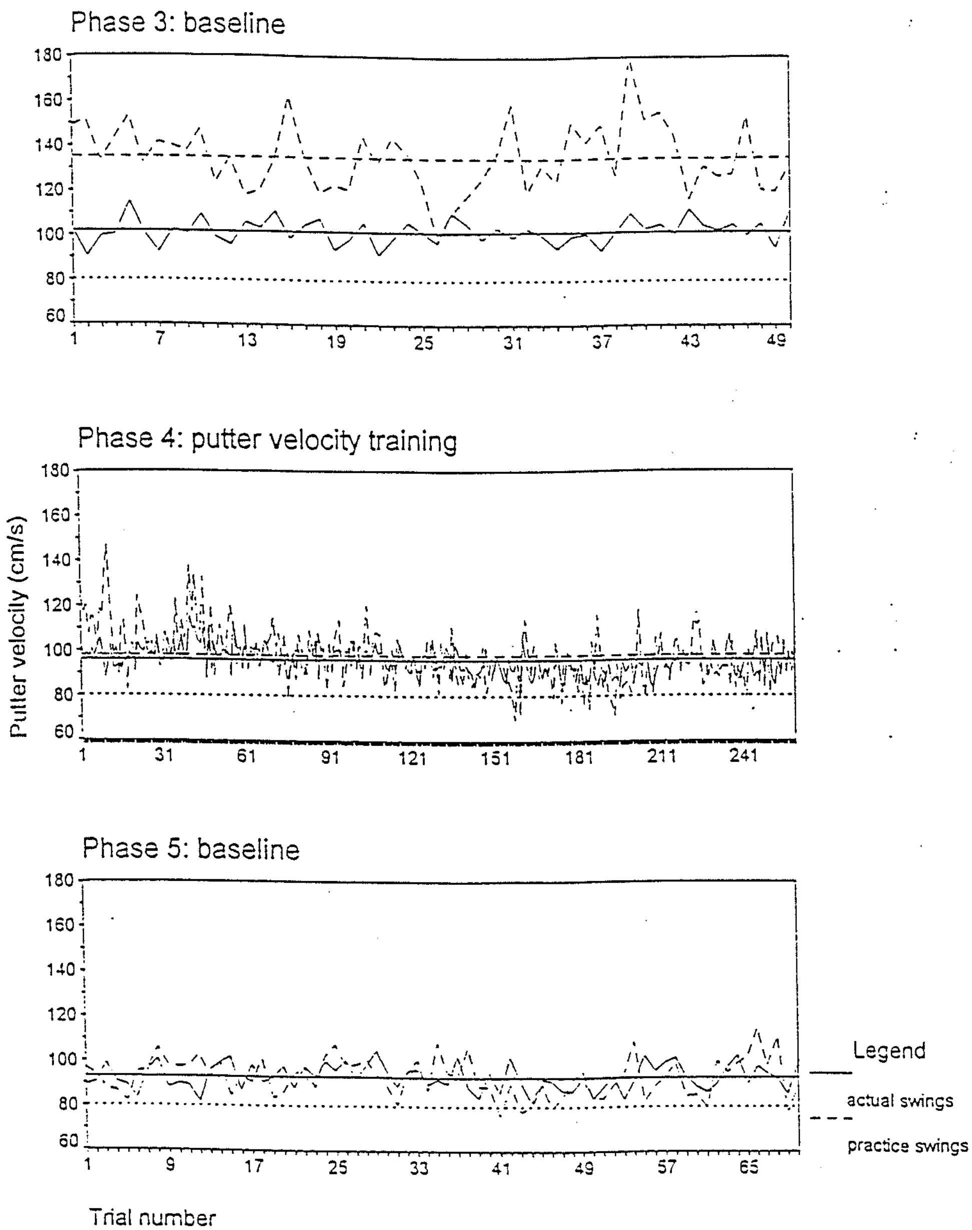
LSD tests were conducted comparing both practice and actual swingpath angles across the first three phases; baseline versus swingpath angle training, and swingpath angle training versus return-to-baseline. These tests revealed significant differences ($p < .05$) between both comparisons for actual swings, and between baseline and training for practice swings.

Practice and actual swing performance as a function of putter velocity training. Analysis of the putter velocity training for Participant 2, revealed that the mean velocities during the second baseline phase were very different for practice (M = 135.28 cm/s, SD = 15.12 cm/s) and actual (M = 102.17 cm/s, SD = 5.57 cm/s) putts (see Figure 10). Although the actual putts were quite a bit closer to the mean training value (M = 80.39 cm/s) that would be used in the next phase, both values were fairly high. During the putter velocity training phase, the mean putter velocity for actual putts dropped slightly to 95.75 cm/s (SD = 6.14 cm/s), while for practice putts it dropped considerably (M = 98.25 cm/s, SD = 12.30 cm/s).

Figure Caption

Figure 10. Putter velocity of practice and actual swings per trial during phases 3-5 for Experiment 2, Participant 2.

Putter velocity per trial: Experiment 2, Participant 2



Solid and dashed reference lines denote mean values per phase

Dotted reference line denotes mean training value used during phase 4

As a result, both values were very close together and considerably closer to the mean training value. However, these values still fell outside of the optimal training range of 79.55 to 81.24 cm/s. During the final return-to-baseline phase both the practice and actual mean putter velocities dropped slightly and were basically identical (M_p = 93.20 cm/s, SD_p = 8.71 cm/s, M_a = 93.13 cm/s, SD_a = 5.78 cm/s).

The graph of the mean velocity of the practice and actual swings per block (see Figure 11) illustrates a gradual downward trend for the putter velocities of actual swings. It also shows the initial drop of the mean practice swing velocities from baseline to training and the eventual shadowing of the mean actual swings to the practice swings.

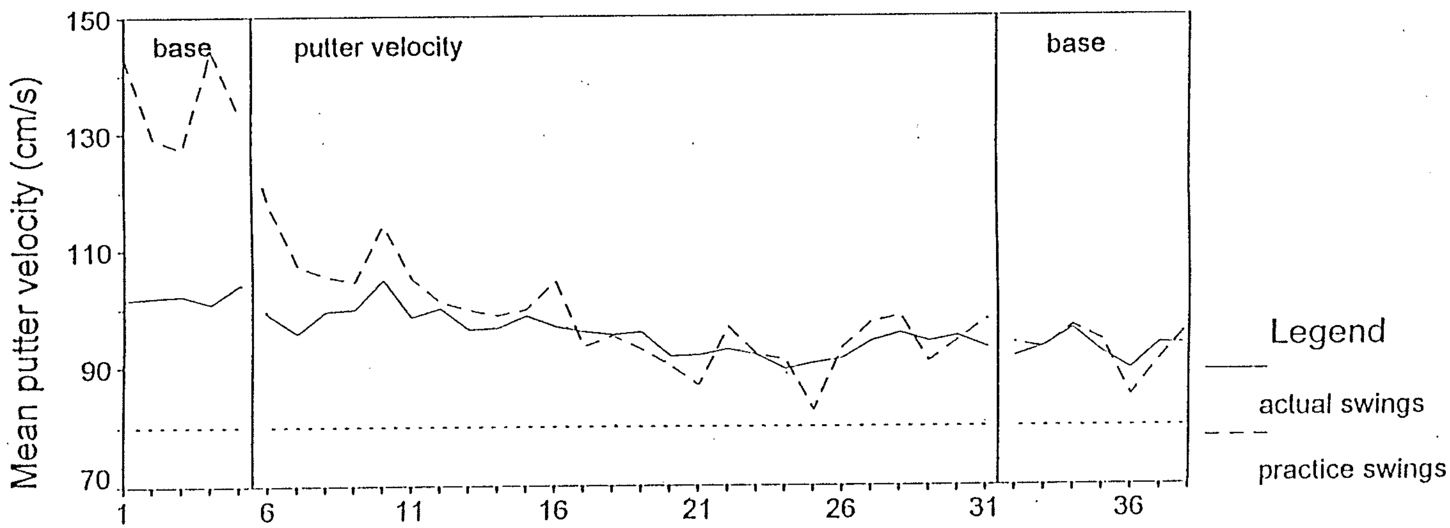
LSD tests were conducted comparing both practice and actual putter velocities across the final three phases; first return-to-baseline versus putter velocity training, and putter velocity training versus final return-to-baseline. These tests revealed significant differences ($p < .05$) in all the comparisons for both practice and actual swings.

Figure Caption

Figure 11. Mean putter velocity of practice and actual swings per block during phases 3-5 for Experiment 2, Participant 2.

Mean putter velocity per block

Experiment 2, Participant 2, Phases 3 - 5



Blocks of 10 trials

base: baseline, putter velocity: putter velocity training

Dotted reference line denotes mean putter velocity training value

Comparison

A comparison of the results of the two participants may help summarize some of the findings. However, the reader should bear in mind that the two participants received the training phases in the opposite order to control for order effect. Participant 1 received putter velocity training first, whereas Participant 2 received swingpath angle training.

On target, on weight, and on line performance. Looking at the first baseline phase, Participant 1 demonstrated modest putting skill to begin with, recording 12% of putts on target. Participant 2 was somewhat less skilled, recording only 2% of putts on target in the first baseline phase and no putts on target during the baseline phase just prior to putter velocity training. However, in the baseline phase just prior to putter velocity training, Participant 1 recorded 18% of putts on weight while Participant 2 recorded 22%.

For Participant 1, putter velocity training was associated with a slight drop in scores for putts on target and a slight but steady improvement for putts on weight compared to the previous phase. For Participant 2, this same training was associated with a slight increase in scores for putts on target, and a slight decrease for putts on weight.

In the return to baseline phase following putter velocity training, Participant 1 demonstrated a drop to zero putts on target, but a continued improvement in the percentage of putts on weight. Participant 2 recorded a continued, slight improvement for putts on target, and a marginal improvement for putts on weight.

With swingpath angle training, Participant 1 showed strong improvement for both putts on target and on line from scores recorded in the prior baseline phase. Participant 2 recorded a slight increase in putts on line and almost no change for putts on target over these same two phases.

In the return to baseline phase following swingpath angle training, Participant 1 recorded a drop in both putts on target and on line, but these values were still higher than in the previous baseline phase. The scores for Participant 2 also declined in this phase with putts on target falling to zero and putts on line returning to the level of the previous baseline phase.

LSD tests conducted on the on target, on weight, and on line data for each of these participants revealed that although there appear to be differences in scores across phases, they were not always significant. Only swingpath angle training for Participant 1, resulted in significantly superior on target, and on line performance over their respective baseline phases.

Practice and actual swing performance as a function of putter velocity training. In the baseline phase preceding putter velocity training both participants had mean actual swing velocities of approximately 100 cm/s and mean practice swing velocities that were even higher. Participant 2 recorded a mean practice swing velocity of over 135 cm/s.

During putter velocity training both participants exhibited an immediate and dramatic reduction in practice swing velocities. There was a reversal in mean velocities for Participant 1 with practice swings becoming closer to the desired value than actual swings. In fact, the mean practice swing velocity for Participant 1 was within the optimal range being trained for. Although there was no reversal in mean practice and actual swing velocities, the mean practice swing velocity for Participant 2 dropped considerably during putter velocity training, and was very near the optimal range being trained for. The actual swing velocities for both participants also decreased during putter velocity training. Rather than the sharp drop found in practice swing velocities, the actual swing velocities showed a gradual downward trend for both subjects, and a slightly more rapid drop about one third of the way into training for Participant 1. Overall, the mean actual swing velocities dropped by over 8 cm/s for Participant 1 and over 6 cm/s for Participant 2.

In the return to baseline phase following putter velocity training, the data for Participant 1 revealed an increase for both practice and actual swing velocities. The mean velocity for actual swings increased only slightly, while the mean for practice swings increased quite a bit more. Even so, these means maintained the reversal found in the previous phase whereby the practice swings were closer to the desired value than the actual swings. For Participant 2, there was a continued slight drop for both means and their values became almost identical during this return-to-baseline phase.

LSD tests conducted on this data for both of these participants revealed that there were significant differences between all phases of these variables with one exception. There was no significant difference between treatment and the return to baseline phase of mean actual swing velocities for Participant 1.

Practice and actual swing performance as a function of swingpath angle training. In the baseline phase preceding swingpath angle training, Participant 1 had a mean swingpath angle that was fairly high, at around the zero degree mark for practice swings, and just above the optimal training range used in the following phase, for actual swings. Participant 2 had mean swingpath angles that were both higher than Participant 1. For actual swings the mean was a degree and a half above zero, while for practice swings it was higher yet.

During the swingpath angle training phase both participants recorded a drop in the two mean values. For Participant 1 the mean swingpath angle for practice swings dropped to just above the optimal range while the mean for actual swings went from just above to just below the optimal range. Participant 2 recorded a large drop in the mean swingpath angle for practice swings and a slightly smaller drop in mean actual swings. These changes brought the two values much closer together at about the zero degree mark. The overall pattern for practice and actual swings recorded by Participant 2 was a downward trend to the optimal range during the first third of the phase. This was then followed by a reversal of both values to around the zero degree mark for the remainder of the phase.

In the return to baseline phase following swingpath angle training, the mean values for Participant 1 swingpath angles both dropped. The mean for practice swings dropped to within the optimal range while the mean for actual swings continued to drop farther below the optimal range. For Participant 2 there was no real change in the mean practice swingpath angle and only a slight lowering of the mean actual swingpath angle. Both of these values remained closer to zero degrees than the mean optimal value of -4.25 degrees.

LSD tests conducted on this data for both of these participants revealed that there were significant differences between all phases of these variables with one exception. There was no significant difference between treatment and the return to baseline phase of mean practice swingpath angles for Participant 2.

Discussion

The main goal of Experiment 2 was to use the tracking system to analyze the putting stroke of novice golfers, compare their data to those of the low handicap golfers studied in Experiment 1, and to provide feedback on these differences in an attempt to improve the novice golfers putting ability.

As shown in Experiment 1 the system has the ability to analyze a golfer's putting stroke. As for making a swing by swing comparison between the data collected from the low handicap golfers, with that of the novice golfers, all that was required was a few lines of extra programming. Once the comparison was made, the novice participant was then provided with some basic feedback on their practice swing.

The feedback itself was fairly crude, consisting of a verbal, three-point Likert scale ranging from "too little" to "too much" of the variable being trained. This verbal feedback was also accompanied by a diagram that demonstrated the verbal prompts in a visual format (see Appendix A). Some might argue that this feedback was too vague, that telling a participant that their practice swing was "too hard" would only lead to the question of "how much too hard". In reality, there were no such questions asked by the participants, and the loud click that served as an aversive cue for head movement in the Simek and O'Brien (1978) study was an even simpler form of feedback that seemed to effectively increase putting accuracy. The real question regarding the feedback was, did it improve the novice golfers putting ability? In actuality there were improvements, despite the fact that there were several variables that may have interfered with the results. These variables, which include the simulated hole, a sloped putting surface, and the placement and strength of the feedback, will be discussed throughout this section.

On target and on weight performance. During the first baseline phase, it was observed that Participant 1 was slightly more skilled at getting putts on target than Participant 2. Further, this finding held up when looking at putts on target for Participant 2 in the baseline phase just prior to putter velocity training. However, when looking at putts on weight in the phase just prior to velocity training, Participant 2 was slightly superior to Participant 1.

During putter velocity training the findings were mixed. Participant 1 had fewer putts on target but a steady increase in putts on weight, whereas Participant 2 recorded more putts on target and fewer on weight when compared to the previous phase.

In the return to baseline phase following putter velocity training both participants maintained the level of proficiency attained in the putter velocity training phase with the exception that Participant 1 failed to record any putts on target.

Statistical analyses conducted on the on target and on weight data, revealed that there were no significant differences in these variables across phases. Consequently, it would appear that the putter velocity training provided had no clear effect on putting performance. However, putting performance was affected, but the changes did not necessarily result in more putts coming to rest in the required areas of the final position grid. After all, it was specific putter motions that were being reinforced not target hits and other variables assessed, such as putter velocity and swingpath angle, confirmed this.

On target and on line performance. In the baseline phase just prior to swingpath angle training Participant 1 recorded no putts on target and only a few putts on line. Similarly, Participant 2 recorded almost no putts on target and approximately the same percentage of putts on line as on target.

During swingpath angle training Participant 1 showed some improvement for both putts on target and on line, whereas Participant 2 had no change in putts on target and a slight increase for putts on line.

In the baseline phase following swingpath angle training, scores for Participant 1 dropped, but remained higher than in the baseline phase prior to training. For Participant 2 both scores basically reverted to the pre-training levels.

Statistical analyses conducted on the on target and on line data revealed that the only significant differences in these variables across phases were between baseline and swingpath angle training for participant 1. Although less extensive than expected, this finding is encouraging because it shows that the swingpath angle training is capable of significantly altering the putting outcome. The fact that the other statistical tests failed to reach significance, suggests that the swingpath angle training provided had no clear effect on putting performance. However, as in the case of putter velocity training, putting performance was affected but the changes were not easily detectable by these measures. The specific putter motions being reinforced, were better assessed through the variables of putter velocity and swingpath angle than the measures associated with the final position grid.

Interference with on target, on weight, and on line performance. One problem with the set up of the final position grid was the fact that the participants were required to try to get the golf ball to come to rest on a simulated hole. It was originally felt that the painted target would be useful because it would create a higher requirement for accuracy of putter velocity and remove the confound of the ball being stopped or deflected from its course by the hole. On a golf course, any putt that has the correct line to the hole and a velocity sufficient enough to carry the golf ball that distance, or even a velocity that would carry it a foot or two past the hole, would generally result in a successful putt. Although it is true that the simulated hole did reduce the range of optimal velocities and did not appear to cause difficulty for the low handicap golfers, it probably made the task too difficult for novice golfers to master in such a brief period. In short, the novice golfers may have shown better on target performance as a result of training if a real hole rather than a simulated one had been used.

An additional problem with the experimental set up was the fact that the putting surface was not perfectly level. When viewed with the naked eye the putting surface appeared level and flat making the task appear to be a straight line putt, but this was not the case.

Prior to laying down the carpet that was used as the putting surface, the floor of the experimental room was checked and appeared to be level. Despite this precaution, there remained a slope to the floor which although undetectable by the earlier assessment, affected the trajectory of the golf ball. In golfing terms, the experiment was conducted on a surface with a "break". Given that the putting distance was 183 cm and the mean optimal training value for swingpath angle was -4.25 degrees the mean break was -13.60 cm from the center of the simulated hole or -8.60 cm from the edge. Although this situation is not uncommon in the sport of golf and the more complicated putt did not appear to cause any difficulties for the low handicap participants, it would have been better to have had a straight-line putt for the novice golfers. The novice golfers may have shown better on target and on line performance as a result of training had the putting surface been perfectly flat and level.

Some further reasons for the lack of improvement in putts on target, on weight, or on line are as follows: Firstly, it was specific putter movements, not target hits, that were being reinforced. It was hypothesized that improved swings would lead to more target hits; however, this was not the case. Secondly, feedback was provided on practice swings not actual swings. It was hypothesized that feedback on one putt, the practice swing, would lead the largest change in behavior to occur in the following putt, the actual swing. However, as will be discussed in the next section, the participants appear to have discriminated between the two types of putts. The feedback had the largest effect on the practice swings, which were not directly related to on target, on weight, or on line performance.

Practice and actual swing performance as a function of putter velocity training. In the baseline phase preceding putter velocity training both participants had high velocities for both actual and practice swings. These velocities were well above what was required for a successful putt, as determined in Experiment 1.

In the putter velocity training phase there was an immediate and dramatic reduction in practice swing velocities for both participants. Further, both participants also showed a gradual downward trend in actual swing velocities.

In the return to baseline phase following putter velocity training the results were rather different for the two participants. Participant 1 had a slight increase in the actual velocities and a larger increase in the practice ones. Participant 2, on the other hand, continued to approach the optimal range and recorded a continued slight drop in both velocities.

Statistical analyses conducted on these data confirmed that there were significant differences between almost all phases of both practice and actual swings for both participants. The only exception was for Participant 1, where there was no significant difference between putter velocity training and the return-to-baseline phase for actual swings.

The putter velocity training phase findings suggest that the feedback provided to the participants was having the largest effect on the practice swing velocities. This is contrary to the original hypothesis which was that the participants would not differentiate between the practice and actual putts, treating each simply as a putt. Although it might be thought that providing feedback on a putting stroke would lead to the most significant changes occurring in the putting stroke that immediately followed, this was not the case. It appears instead that the participants discriminated between practice and actual swings rather than treating them both simply as putting strokes. Consequently, feedback on the practice swings resulted in larger effects for practice swings and smaller effects for the actual swings.

Given that the largest effects were found for practice swings, one still might expect that these effects might transfer to actual swings as well. There were changes, and they were significant; however, these changes were smaller and less immediate than those found for the practice swings.

It would be interesting to know if the findings for the practice swings would have been even more dramatic had there not been an actual swing separating each practice swing. Similarly, would the effects on the actual swings have been more rapid and dramatic had the feedback been provided on the previous actual swing? Moving the feedback to the actual swings would also help the novice training coincide with the low handicap data which was originally collected on their actual swings.

During the design of this study there was a point at which the writer considered providing feedback on the actual swings. However, this idea was dropped because it seemed ridiculous to use this elaborate tracking system to provide feedback on a golf swing in which the most accurate feedback would come from the ball itself. Further, since it was felt that the majority of golfers make a practice swing prior to making their actual swing it seemed only natural to provide the feedback at this point. In hindsight, it makes sense to provide the feedback on the actual swings, as these are the swings that really need to be altered and this is exactly what a golf pro would do. If the view of the ball was still an issue its path could be obscured from the learner's view during training. However, this would probably not be necessary because knowing where the golf ball went is one thing, but the tracking system, like the golf pro, could tell the student why the ball went where it did. Even if the feedback was moved to the actual swings there are still two further questions that beg to be answered. These are, would the effects on the actual swings vary depending on whether or not a practice swing separated the actual swings, and what if feedback was given on both swing types? Only further studies will tell.

Looking at the findings from the return to baseline phase following putter velocity training, we find two different results. Participant 1 had a reversal from the downward trend in the training phase, suggesting the feedback from the previous phase might have been controlling the behavior. On the other hand, Participant 2 continued the downward trend towards the optimal range. This finding suggests that learning had taken place, or that the skill was under the control of the visual feedback provided from watching the outcome of the actual putts.

One possible reason for this difference between the two participants is the order in which the training phases were presented. Participant 1 may have remained under the influence of the velocity training feedback because correct velocities alone do not lead to successful putts. At this point in the study, Participant 2 already had the benefit of the swingpath angle training. Assuming that Participant 2 had already learned something about the correct swingpath angle, and had just learned something about the correct putter velocity, the likelihood of getting actual putts on or near the target increased. This increased frequency of positive visual feedback may itself have been controlling the behavior during the return to baseline phase.

Practice and actual swing performance as a function of swingpath angle training. In the baseline phase preceding swingpath angle training it was observed that the two participants registered rather different results. Participant 1 had swingpath angles for practice swings that were close to zero degrees, and angles for actual swings that were much lower and closer to the desired range. On the other hand, Participant 2 had practice and actual swingpath angles that were both above zero degrees.

In the swingpath angle training phase the practice and actual swingpath angles dropped for both participants. The swingpath angles for Participant 1 fell on both sides of the optimal range, with practice swings just above and actual swings falling just below.

For Participant 2, the practice and actual swingpath angles came together and fell around the zero degree mark.

In the return to baseline phase following swingpath angle training both practice and actual swingpath angles continued to drop for Participant 1. The swingpath angles for practice swings fell within the optimal range, while for actual swings they dropped further below the optimal range. For Participant 2 there was no change in the values for practice swings, but a slight lowering for actual swings.

Statistical analyses conducted on these data confirmed that there were significant differences between almost all phases of both practice and actual swings for both participants. The only exception was for Participant 2, where there was no significant difference between swingpath angle training and the return-to-baseline phase for practice swings.

The fact that the two participants had such different results in the baseline phase prior to swingpath angle training was probably due to the reversed training order. Participant 1 had already received training on putter velocity and therefore had made many actual putts during which it was possible to observe the putting outcome. The practice putt remained straight as one might expect, but the actual putts were made with some compensation for the curve to the putting surface. On the other hand, Participant 2 had received comparatively little experience at the task. Subsequently, both practice and actual swingpath angles were similar and far removed from what was required.

The swingpath angle training phase findings suggest that the feedback provided to the participants was having an effect on their swingpath angles. Both participants altered their practice and actual swingpath angles towards the optimal range. Participant 1 showed the largest effects in the practice swings, once again suggesting that it was these swings that were being associated with the feedback.

Although Participant 2 made alterations to the practice and actual swingpaths which brought them closer to the optimal range, they both still hovered around the zero degree mark. One possibility for this finding is that although the verbal feedback was powerful enough to result in some initial changes in behavior, it was not strong enough to override the visual feedback about the putting surface. As mentioned earlier, the putting surface was deceiving in that it appeared flat, but actually was not. This participant may have been receiving visual cues about the proper swingpath angle from the environment that were too strong for the verbal feedback to overcome.

The findings from the return to baseline phase following swingpath angle training suggest that Participant 1 had learned something about the optimal swingpath angle. Although this participant's actual swingpath values dropped farther below the optimal range, both the practice and actual values were close enough to this range to assume that something was learned about the optimal swingpath angle. Since there was no reversal in the values for Participant 2 in this phase one would have to assume that something was learned in the training phase. However, what was learned remains in question. As mentioned above, changes in the values towards the optimal range suggest that the earlier feedback was slightly effective. However, Participant 2 still had a strong tendency to keep the swings closer to the zero degree mark suggesting a stronger case for control by the visual alignment feedback.

Order effect. To control for the possibility of an order effect, the two participants in this experiment received training on the two main variables in the opposite order. While it is difficult to make any firm conclusions regarding order effects, some general findings are discussed.

As noted in the previous sections there were few significant findings between phases for putts landing on target, on weight or on line; however, there was a difference between the two participants. Participant 1 showed some significant effects in the second training phase where swingpath angle training improved on target and on line performance over the baseline phase between the two treatment phases. This hints at the possibility that it is advantageous to receive putter velocity training prior to swingpath angle training.

Looking at the putter velocity training portion of the experiment, both participants recorded excessively high practice and actual mean velocities in the baseline phase just prior to training. During putter velocity training, the mean velocities of both participants dropped toward the optimal range. In the baseline phase following training, the mean velocities for Participant 1 increased away from the optimal range while those for Participant 2 continued to drop. As mentioned above, these findings suggest that Participant 1 was under stimulus control of the verbal feedback provided in the previous phase, whereas Participant 2 was under stimulus control of the ball outcome. This finding makes sense in terms of order effects since at this point in the study Participant 2 had already received training on both experimental variables. Therefore, Participant 2 had the two basic skills necessary to get the ball to the target, whereas Participant 1 only had one.

In the baseline phase just prior to the swingpath angle training, Participant 1 had a mean practice swing angle near zero degrees and an actual swing angle that was below zero degrees, and therefore even closer to the optimal training value. Participant 2, on the other hand, had high swingpath angles for both practice and actual swings. These findings coincide with the prior experiences of both participants. Participant 2 was just starting the experiment and had no experience with the task while Participant 1 had already experienced putter velocity training. Although he had received no training on swingpath angle at this point, Participant 1 had the opportunity to observe the path of the ball during the actual swings of putter velocity training. As a result, the actual swings could be corrected for the curvature of the putting surface.

During swingpath angle training, the mean angles of both practice and actual swings for both participants changed in the desired direction. For Participant 1 they dropped below zero degrees and approached the optimal range while for Participant 2 they hovered around the zero degree mark. The behavior of Participant 1 appeared to be under the control of the verbal stimulus provided by the experimenter whereas that of Participant 2 was still at least partially controlled by the visual stimulus which suggested that the swingpath should be at zero degrees. The fact that Participant 1 had received putter velocity training first, may have allowed him to realize that the putting surface was not level and therefore contributed to credibility of the verbal directions.

In the return to baseline phase of swingpath angle training, the mean scores of Participant 1 continued to drop and remained near the optimal range whereas those of Participant 2 remained the same as in the training phase. This finding suggests learning to the relevant stimuli. That is, Participant 1 had come under the control of the ball outcome which is what one would expect since this participant had received training on both the experimental variables and had the basic skills necessary to get the ball on target. Participant 2 was under the control of the visual feedback of the putting surface which appeared to be flat and level.

In general these findings suggest that the preferred order for training is putter velocity prior to swingpath angle; however, one must keep in mind that there were only two participants and that the problem with the slope of the putting surface made the task deceiving.

The goal of Experiment 2 was to use the tracking system to analyze the putting stroke of novice golfers, compare their data to those of the low handicap golfers studied in Experiment 1, and to provide feedback on these differences in an attempt to improve the novice golfers putting ability. As shown, the system was quite capable of analyzing putting strokes, comparing the novice data to findings from the low handicap golfers and providing feedback. There are some questions about the feedback that still need to be answered, but it was capable of affecting performance. The biggest question was whether or not the ability of the novice golfers was improved. The findings show that there were improvements in the novice golfer's abilities, but there were several factors such as, the simulated hole, the sloped putting surface, and the placement and strength of the feedback, that may have interfered with more substantial improvements.

Discussion Of Overall Study

One of the most obvious questions to ask with regards to this study is, what is the advantage of using all this equipment to teach people how to putt? The simple answer is that there probably is no advantage. Similar results probably could have been achieved by taking golf lessons for the same period of time; however, teaching people how to putt was not one of the primary aims of the study.

The primary aim of the study was to test the automated tracking system developed by Pear and Legris (1987) on a potentially useful target behavior with human participants. Using the system on human participants was not new (Pear 1997), but this study was the first to break away from shaping participants to find a point in a predetermined three dimensional space. It was argued that although finding a target point is useful, for many human movements the path towards the target area is just as important as getting to the target area itself. Being able to shape a movement pattern would open the door to shaping more complicated skills such as those found in daily life, in the arts, and in sport.

As this was the first experiment to take the tracking system and apply it to learning a sport skill, it was decided that the study should be kept simple and should concentrate on providing basic feedback, saving shaping of movement patterns for future work. The golf putt was chosen as the target skill because of its compatibility with the tracking system. Also, a review of the literature revealed that although books, magazines, and articles about golf abound, there is very little research on the learning process itself.

In a study by Simek and O'Brien (1978), a clicking sound was used as an aversive cue to successfully increase putting accuracy. The present study partially replicated this work by using basic feedback to improve the putting stroke of the two participants. It also extended the earlier study by showing that other components of the golf putt are also amenable to this type of feedback.

In a second study by McGlynn et al. (1990), a laser and mirror arrangement was used to take extremely precise angular measurements of putting alignment. The present study partially replicated this work by using the tracking system to make similar angular measurements. It also extended this work by measuring several other components of the golf putt and doing so while the club was in motion, with and without a golf ball.

Conclusion

From an overall perspective it seems reasonable to conclude that this study provided some useful information on the tracking system, the golf putt, and training novice golfers. The first experiment demonstrated the tracking system's capabilities, and provided valuable information about the golf putt. The second experiment showed that feedback provided by the system can be used to improve the putting stroke of novice golfers. Throughout the course of the study some difficulties were also encountered; however, these have led to some interesting possibilities for future research.

Experiment 1

Experiment 1 demonstrated that the tracking system has the ability to accurately record useful data on the putting stroke of several low handicap golfers. The links between both putter velocity and swingpath angle with the final resting position of the golf ball were clearly shown. Similar effects may be found for the variable of clubface angle when a future version of the system is available. This system, capable of tracking multiple points, could measure clubface angle at the point of ball contact rather than during the initial putter alignment. Besides the multi-point tracking system, the only other suggestion for improvement in experiment 1 was the replacement of the final position grid with a more finely calibrated measurement device. Improving this measure would remove some of the error inherent in the final position grid and therefore improve the odds of detecting significant findings. Finally, an interesting result was found for the last of the four main variables, putter acceleration. Although it is generally accepted that the putter should be accelerating at the time of ball contact, the probability of the ball landing on target in this experiment, was higher when the putter was decelerating. Further study is required to determine whether this finding will hold up or if it is simply an anomaly.

Experiment 2

In Experiment 2 the tracking system was used to analyze the putting stroke of novice golfers. These data were compared to those of the low handicap golfers studied in Experiment 1, and feedback on these differences was provided. This feedback led to the improved putting ability of the novice golfers.

When looking at putts on target, on weight, or on line the results were mixed and there were few significant findings. This could have been due to several factors, such as: the use of a simulated hole as the target, the uneven putting surface, the fact that these data were collected from actual swings that were less affected by the treatments, and the fact that these data were an indirect measure of putting improvement. Future studies on this skill might benefit from the use of a raised platform that can be fine tuned for level and allows the golf ball to drop into a regular cup.

The results of the putter velocity and swingpath angle training were exciting, in that there were significant improvements in both practice and actual swings for both participants. The writer was surprised that the more dramatic findings were in the practice swings rather than the actual swings, but this result can be explained by the fact that it was actually the practice swings that received the feedback. Some suggestions for future research included keeping the feedback on the practice swings but dropping the actual swings, and switching the feedback to the actual swings, both with and without practice swings.

Lastly, during swingpath angle training one of the participants appeared to rely more on the visual feedback of aligning the putter perpendicular to the target rather than the verbal feedback provided by the experimenter. Future studies may overcome this problem by altering the feedback provided so that it is more powerful, or altering the putting surface so that it is perfectly level.

Overall Study

With this study, the tracking system has successfully made the move from human research that parallels the earlier pigeon studies conducted by Pear and Legris (1987), and has proven that the system is also amenable to practical tasks. With some future improvements, it should be possible to expand the number of variables investigated and study them in greater detail. Further, the system could also be modified for use on other skills in addition to putting.

Although this study was successful in its present form, it has clearly raised several new questions that future studies may answer. Several alterations to the current study have been suggested for future research, and it is hoped that some of these changes will prepare the tracking system for the ultimate goal of shaping a movement pattern.

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Appendix A

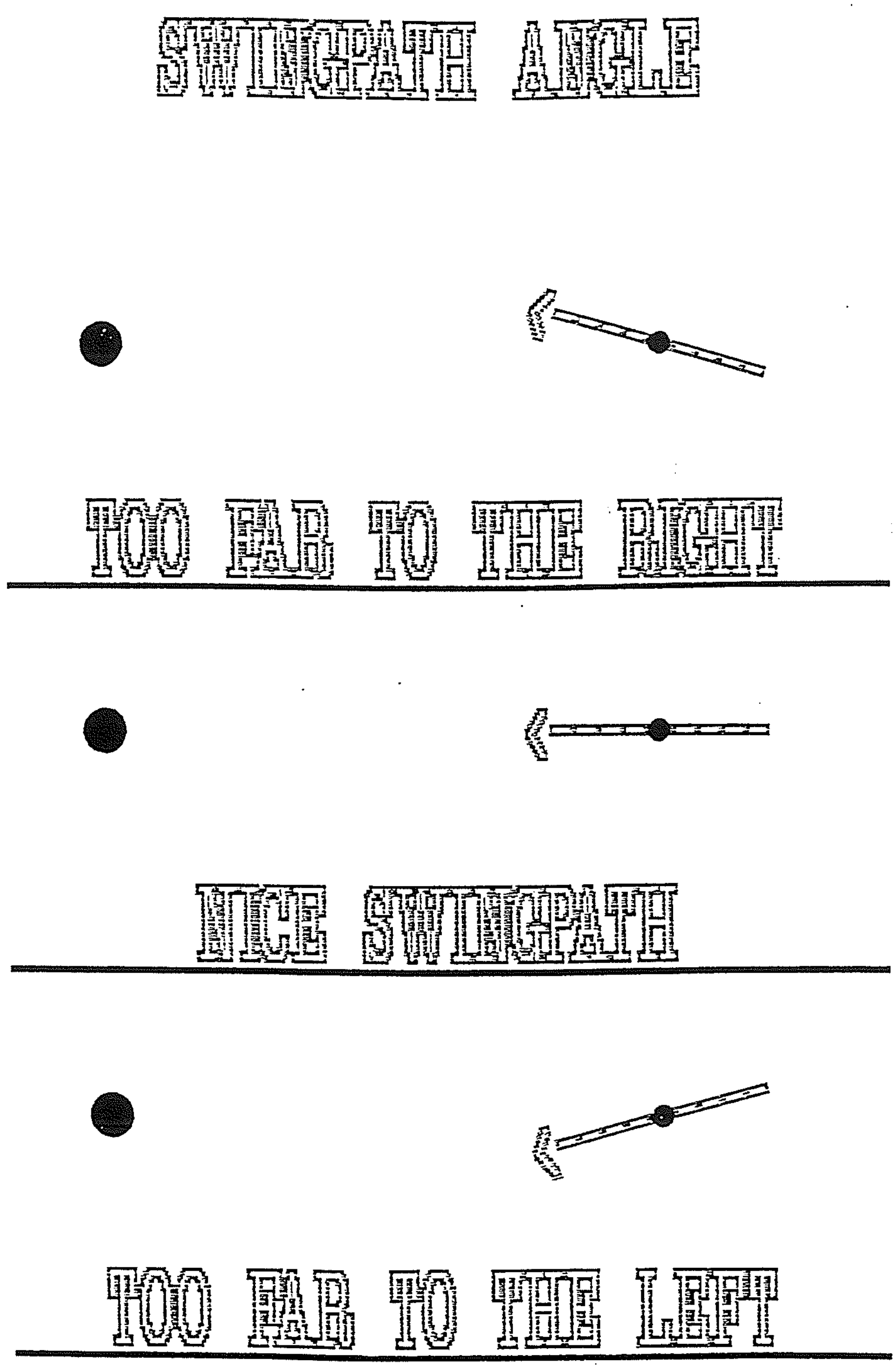
Feedback Diagrams

INITIAL CLUBFACE ANGLE

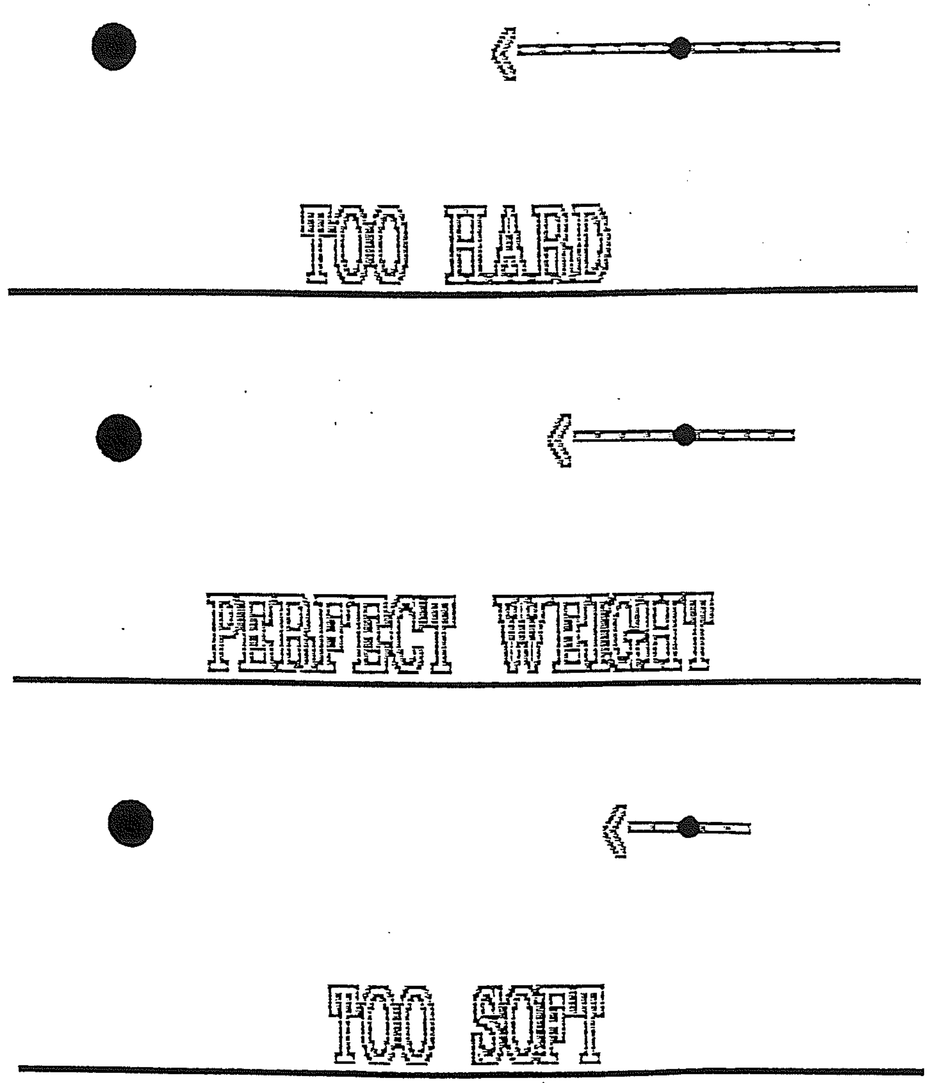
TOO FAR TO THE RIGHT

GOOD ALIGNMENT

TOO FAR TO THE LEFT

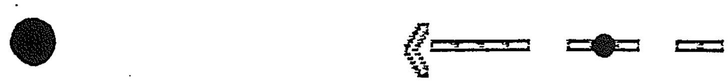

SWINGPATH ANGLE
TOO FAR TO THE RIGHT
NICE SWINGPATH
TOO FAR TO THE LEFT

PUTTER VELOCITY



PUTTER ACCELERATION

TOO MUCH ACCELERATION



EXCELLENT ACCELERATION

TOO LITTLE ACCELERATION

Appendix B

Preferred Putting Style Checklist

Preferred Putting Style Checklist

The following checklist will be used in Experiment 1, to assess the putting stroke of low handicap golfers, in order to determine whether or not the subject uses an unorthodox style. The checklist will also be used in Experiment 2, to provide novice golfers with instruction on proper putting technique, and to assess the effectiveness of this training.

Definitions

Form assessment prior to the golf swing.

A. Grip:

Hands should be tight together with the right hand lower on the club shaft than the left (interlocking or overlapping of the fingers is acceptable).

B. Putter placement:

Putter should be flat on the ground, approximately in the middle of the stance, with the sweet spot of the club directly behind the ball.

C. Stance:

Feet should be approximately shoulder width apart with the knees slightly bent.

D. Balance:

Weight should be evenly distributed across the balls and heels of the feet (slightly more weight on the left foot is acceptable).

E. Eye Gaze:

Eye gaze should be close to directly over the ball.

F. Alignment:

Feet and putter blade should be aligned at approximately a 90 degree angle to the desired path of the ball.

Form assessment during the golf swing.

G. Swingpath:

Path of the putter should be approximately straight along the desired path of the ball.

H. Backswing:

Backswing should be slightly smaller than the follow through.

I. Shoulders:

Putt should be performed with the shoulders rather than the arms or wrists ("V" shape of arms should remain constant throughout swing).

J. Head:

Head should remain still and the golfer should look up only after the putting stroke is complete.

Preferred Putting Style Checklist

Using the following checklist, assess the putting style of the golfer during several putting strokes. During this assessment the golfer should exhibit at least three putts in which each item is performed correctly. If an error is noticed on any of the items, inform the subject, and restart the assessment. If errant behavior continues, the subject may have to be excluded from further study.

Checklist Subject #:_______

Form assessment prior to the golf swing.

A. Grip:	___	___	___
B. Putter placement:	___	___	___
C. Stance:	___	___	___
D. Balance:	___	___	___
E. Eye gaze:	___	___	___
F. Alignment:	___	___	___

Form assessment during the golf swing.

G. Swingpath:	___	___	___
H. Backswing:	___	___	___
I. Shoulders:	___	___	___
J. Head:	___	___	___