5-1990

Oculomotor considerations in golf putting consistency

Tamara K. Mathison
Pacific University

Melissa S. Viker
Pacific University

Oculomotor considerations in golf putting consistency

Abstract

This study was designed to investigate the influence of oculomotor posture (fixation disparity and/or heterophoria) on a visuomotor task, golf putting. Although studies have shown that inducing changes in heterophoia at distances <1 meter causes errors in distance>judgements, previous studies which have considered only naturally occuring fixation disparity and heterophoria have not been able to demonstrate a relationship between direction and/or magnitude of fixation disparity (or heterophoria) and spatial judgement errors as measured by golf putting error. The subject sample of 62 participants consisted of 36% amateur golfers, 11% club pros and 53% LPGA tour pros. Following measurement of the subjects' oculomotor status, each subject attemped 6 putts with no auditory or visual feedback. Results indicate subjects with a higher magnitude and/or greater instability of fixation disparity were less successful in task performance. Although oculomotor measures are not predictors of left-right and long-short putting errors, we found they may be predictors of the golfers ability to consistently aim accurately and therefore make less endpoint putting errors.

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Bradley Coffey

Subject Categories

Optometry

OCULOMOTOR CONSIDERATIONS IN GOLF PUTTING CONSISTENCY

THESIS BY
TAMARA K. MATHISON
MELISSA S. VIKER

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
for the degree of
Doctor of Optometry
May, 1990

Advisers:

Bradley Coffey, O.D.
Alan Reichow, O.D.

AUTHORS

TAMARA K. MATHISON

MELISSA S. VIKER

ADVISORS

BRADLEY COFFEY, O.D.

ALAN REICHOW, O.D.

TABLE OF CONTENTS

Acknowledgement

We express our gratitude to Steve Agnes for spending two beautiful days with us at the golf course collecting data. We also thank our advisors, Bradley Coffey and Alan Reichow, for their guidance and commitment to this project.

Abstract

This study was designed to investigate the influence of oculomotor posture (fixation disparity and/or heterophoria) on a visuomotor task, golf putting. Although studies have shown that inducing changes in heterophoia at distances <1 meter causes errors in distance judgements, previous studies which have considered only naturally occuring fixation disparity and heterophoria have not been able to demonstrate a relationship between direction and/or magnitude of fixation disparity (or heterophoria) and spatial judgement errors as measured by golf putting error. The subject sample of 62 participants consisted of 36% amateur golfers, 11% club pros and 53% LPGA tour pros. Following measurement of the subjects' oculomotor status, each subject attempted 6 putts with no auditory or visual feedback. Results indicate subjects with a higher magnitude and/or greater instability of fixation disparity were less successful in task performance. Although oculomotor measures are not predictors of left-right and long-short putting errors, we found they may be predictors of the golfers ability to consistently aim accurately and therefore make less endpoint putting errors.

Introduction

The present study investigates the relationship of fixation disparity to the performance of a distance visuomotor task, golf putting. Fixation disparity is a small misalignment of the two eyes that occurs during binocular viewing. Despite this misalignment, single binocular vision is maintained if the fixation points of the two eyes fall within Panum's fusional areas. Panum's fusional area is an area of less than 0.50 prism diopters or 0 to 20 minutes of arc on the retina (Dowley, 1989). This area allows for two points that are not perfectly aligned on the retina to be seen as a single point thus eliminating diplopia. Two theories of the role of fixation disparity have been suggested. It may be an error signal necessary to maintain a specific vergence position (Schor, 1980) or a result of stress on the binocular visual system (Dowley, 1989).

Several studies have investigated the effects of oculomotor cues on perceived distance (Ebenholtz and Wolfson, 1975; Paap and Ebenholtz, 1976,1977; Ebenholtz, 1981; Shebilske, et al. 1983). These studies have demonstrated a link between oculomotor tonus and distance perception via changes in perceived distance following an induced change in heterophoria. The change in heterophoria was induced in these studies by sustained fixation of a target at various convergent demands (Ebenholtz and Wolfson, 1975), prolonged fixation of a near target (Ebenholtz, 1981; Shebilske, et al 1983), or by wearing spectacles with prism or lenses to optically create an increase or decrease in vergence or accommodative demand (Paap and Ebenholtz, 1976,1977). Results of these investigations show an induced esophoric shift resulted in greater perceived distance whereas an induced exophoric shift resulted in lesser perceived distance.

Although these studies used a shift in heterophoria as the indicator of a change in oculomotor tonus, an induced change in the heterophoria will create a change in the fixation disparity in the opposite direction. Therefore, an induced esophoric shift will create an exo fixation disparity and an induced exophoric shift will create an eso fixation disparity (Schor, 1979; Ogle, 1967). Due to the relationship between fixation disparity and heterophoria a link can be drawn between previous studies with heterophoria and this study using fixation disparity as a measure of oculomotor posture.

In a preceding study of golf putting (Fronk and Coffey, 1985), an attempt was made to show that final resting point of a putt could be predicted on the basis of fixation disparity information. This hypothesis was not found to be reliable. It was proposed that perceptual adaptation of motor patterns in response to oculomotor imbalances tends to decrease spatial errors predicted from fixation disparity and/or heteophoria data. In a subsequent study (Makini, Yamamoto and Coffey, 1987) prisms were worn to neutralize habitual fixation disparities. Such prism wear would theoretically induce errors in spatial judgement by disrupting the assumed perceptual adjustment of the motor patterns that had been made in response to previous oculomotor imbalances. No statistically significant change in spatial error tendency between "prism free" and "with prism" conditions occured. Therefore it was concluded that there is not a perceptual adaptation of motor patterns in response to oculomotor imbalances to decrease spatial judgement errors.

In studies performed by Yekta, Jenkins and Pickwell (1987,1989), it was shown that fixation disparity and the symptoms associated with it are increased by binocular stress caused by performing near work. As in most of the other studies that have been performed to study oculomotor interactions with task performance, sections of the 1987 study were performed under unnatural and near point stress conditions. One of the studies noted (Yekta, Jenkins and Pickwell,1987) involved a comparison between the oculomotor measures preceding the work day and again at the end of the work day. Unlike many preceding studies, this design allowed natural environmental stressors to be studied . All of the test conditions investigated showed increased fixation disparity secondary to the given stress factor. However, in the 1989 study the increase in fixation disparity and symptomology was not statistically significant.

It is a possibility then that the competitive stress a golfer experiences may induce changes in the fixation disparity. Such changes in fixation disparity might then lead to increased spatial judgement errors. Evidence of these spatial errors could perhaps be seen in measures of putter alignment and end point putt error in a sample of competitive golfers. The purpose of the current study is to investigate possible relationships between aspects of binocular vision and performance.

Methods

The subject sample of 62 participants consisted of 36% amateur golfers, 11% club pros and 53% LPGA tour pros. The oculomotor status of each subject was determined using a testing battery of 8 tests: sighting eye preference, distance visual acuity, presence and direction of associated phoria, magnitude and stability of fixation disparity, heterophoria and prism adaptation.

Two measures of fixation disparity were taken for each subject to determine a fixation disparity range, which was the difference between the two readings, and a fixation disparity mean, or the average of the two readings. These two parameters were then used to divide the subject sample into specific comparison groups.

The putting portion of the study was conducted outdoors at a local country club. Each morning before testing began the greenskeeper groomed the putting green and cut a new standard size cup (4 1/4" diameter) in a location which gave a straight 4.57 meter (15 foot) putt with no break. To prevent any alignment bias between subjects the green was periodically swept throughout the day.

To enable measurement of the exact aim of the putter face, we used a new laser system designed by Dave Pelz of Independent Golf

Research, an Austin, Texas, private consulting company. This system consists of a laser beam striking the toe of the putter at an angle directly perpendicular to the line created by the putter and the cup. A small lightweight plastic mirror attached at the toe of the putter reflects the beam onto a measuring scale located immediately above the laser source. The actual putter alignment is read directly off this scale (see Fig. 1). To assure accurate readings, the laser's perpendicular alignment was carefully calibrated each morning and prior to each test the mirror attachment was aligned directly perpendicular to the face of the putter.

Each subject attempted 6 putts with no auditory or visual feedback. Auditory feedback was inhibited by foam rubber placed inside the cup. Visual feedback was prevented by an opaque nylon screen mounted on a frame that would drop when contact with the ball was made (see Fig 2). When the screen was retracted the golfer had full view of the putting path, cup and its surround. When the screen was dropped the putting path, cup, surround and the final resting position of the ball were occluded. The final resting position of the ball was measured using a polar coordinate system.

Procedures

Initially each golfer filled out a questionnaire which asked for their name, address, phone number, age, gender, handicap, amateur/professional status, self rating of long and short game, self analysis of how putts are most commonly missed, and eye dominance (see Appendix 1). The oculomotor status testing included eight tests given indoors in the following order (See Appendix 2). Visual acuities were tested using the Snellen acuity chart. Sighting eye preference was determined by asking the subjects to place their right hand on top of their left hand, raise their extended arms and sight the right eye of the tester who was standing 10 feet from the subject. This procedure was repeated with the left hand on top of the right. Each hand orientation was tested twice for a total of 4 readings. The presence and direction of associated phoria was found using the

American Optical vectographic projection slide with the central fusion lock (see fig. 3). This target was also used to determine presence and speed of adaptation to a 2 diopter prism initially oriented BI and then BO. After having the prism in place before the eyes for 5 seconds and again at 10 seconds, the subject was asked if the target looked the same or different. Successful prism adaptation within these time intervals was accomplished if the nonius lines in the target initially showed prism-induced displacement, than slowly realigned. Finally, magnitude and stability of fixation disparity were tested using the prototype Sheedy distance Disparometer (see fig 4). Measurement protocol with this device is similar to that for the Sheedy 40 cm Disparometer (Sheedy,1980). Subjects were asked to report when the two nonius lines were in exact alignment. Two measures were taken to bracket the fixation disparity range. The Disparometer is composed of two vernier lines, the top line being moveable. The top line (visible to the right eye) was moved out of alignment to the right of the bottom line. As the top line was slowly moved to the left the subject was asked to state when the lines appeared in precise alignment. The same procedure was repeated from left to right. In an attempt to partially replicate the head and eye positions used in putting, all oculomotor measurements were taken in an inferior gaze position at the same distance as that used in the putting task.

Initially, the putt distance was set at 3.04 meters (10 feet). However, after the first day it became apparent that a ten foot put was too easy for the highly skilled golfers and we increased our putting distance to 4.57 meters (15 feet) to make the task more challenging. The oculomotor testing distance was also increased to 4.57 meters for the 2nd and 3rd days of testing.

After the golfers completed the oculomotor testing they proceeded to the putting green where a small light weight plastic mirror was attached to the toe of the putter. Once the mirror was properly attached perpendicular to the putter face, the subjects were asked to read the green and report where they felt they needed to aim to successfully make the putt. This was recorded as the *subjective* aim.

The subject then approched the ball and attempted to place the putter in exact alignment with the visualized subjective aim. The actual alignment of the putter face in relation to the hole was measured using the laser system previously described. This measurement was called the *objective* aim. The difference between the subjective and the objective aim was termed the *aim error*.

Each subject attempted 6 putts. Before each putt was attempted an *objective aim* reading was taken. Between each putt the golfers were instructed to make a practice putt at a different hole while the direction and distance of the missed putt was measured and recorded. Distance error was measured in centimeters, direction error was read off a degree scale placed over the cup. (see fig. 5)

RESULTS

Data collected from the entrance questionaire and the oculomotor testing are summarized in Table 1 and Table 2.

For the purposes of our study, the oculomotor measurements of fixation disparity and associated phoria were used to divide the sample into the following comparison groups:

- Low Fixation Disparity - subjects with a mean fixation disparity less than or equal to 2 arc minutes
- High Fixation Disparity - subjects with a mean fixation disparity greater than 2 arc minutes,
- Low Fixation Disparity Range - subjects with less than or equal to 3 arc minutes of difference between readings,
- High Fixation Disparity Range - subjects with more than 3 arc minutes difference between readings,
- Associated Phoria Present - subjects with an associated phoria greater than or equal to 1 prism diopter
- Associated Phoria Absent - subjects with an associated phoria less than 1 prism diopter

The dependent measures (subjective aim, objective aim, aim error and end point putt error) collected from the putting performance tests were analyzed in relation to these comparison groups using the unpaired t-test and one factor ANOVA analysis. Statistical testing indicates that although no significant relationship exists between subjective aim and oculomotor measures, a significant relationship ($p<.05$) does exist between the magnitude of fixation disparity and objective aim. Subjects with greater amounts of fixation disparity tended to have a greater value for objective aim, left or right, as measured away from zero (which would be a putter aimed directly at the cup). A significant relationship ($p<.05$) was also found between the stability of fixation disparity (fixation disparity range) and the ability to aim the putter face consistently in the same position each of the six trials; greater variability in objective aim was found in subjects with larger ranges of fixation disparity.

Subjects who demonstrated greater instability in their fixation disparity measurements ($p<.05$) also showed a greater discrepancy between subjective and objective alignment when analysis of aim error data is performed using an unpaired t-test.

The results of the unpaired t-test analyses also revealed significant relationships ($p<.05$) between the final resting point of the putt and both fixation disparity mean and range measurements. Subjects in the high fixation disparity group missed their putts to the left or right by a greater amount than the subjects with lower amounts of fixation disparity. Subjects with greater fixation disparity range made greater distance putting errors either long or short.

It is important to note, however, we found no relationship between a specific type of putting error, long-short or left-right, and a specific type of fixation disparity, eso or exo, nor was there any such relationship based upon associated phoria. These findings are consistent with those found by Fronk and Coffey and later by Makini, Yamamoto and Coffey.

Subsequent analyses using the unpaired t-test were done to investigate various interrelationships between subjective aim, objective aim, aim error and final resting point of the ball. For the purposes of these analyses the objective aim data were used to divide the golfers into three groups based on the directional tendency of their objective aim. The aim error data were also used to split the subject pool into various groups based on the amount and directional tendency of their aim error. The descriptive information for these groups is listed in Table 3.

The results of these analyses revealed a significant relationship to exist between the left, straight and right objective aim measures and the final putt position to the left or the right (p,.05). The analyses comparing the amount of aim error to the final end point position of the ball revealed that the subjects with the least amount of aim error were able to more accurately place their putts both in the long-short and left-right positions ($p<.05$).

In addition to the fixation disparity analyses, analyses were run between the dependent variables and the presence or absence of an associated phoria. Although none of these analyses revealed a significant relationship they support the trends found in the fixation disparity analyses. Golfers with a measured associated phoria demonstrated greater objective aim measurements as well as greater left/right end putt error. In addition, a significant relationship was found between the amount of associated phoria measured and the mean fixation disparity magnitude measured.

The results of the data discussed are presented in tabular form below (See figures 4-7).

Discussion

The results of this study indicate that subjects with a higher magnitude of fixation disparity demonstrate greater deviations from zero in objective aim measurements than those with lower values of fixation disparity. Likewise, subjects with high variability in their fixation disparity measurements demonstrate greater variability in their objective aim measurements than those subjects with a narrower fixation disparity range. Because the subjective aim measurement remained constant throughout each subject's series of test putts, a varying objective aim, by definition, leads to greater variance in the aim error measurements.

The results of the aim error analysis did, in fact, confirm that subjects with greater variability in their fixation disparity displayed more fluctuation in their aim error measures, and suggest that golfers who have a more stable fixation disparity will be more consistent in their aiming ability than golfers with an unstable fixation disparity. These findings were anticipated in regard to the perspective that fixation disparity fluctuations may cause golfers to perceive the hole to be in a different position than its true location. It is important to note, however, that no predictions of the specific type of putting error likely to occur could be made from any of the fixation disparity measurements. Although oculomotor measures did not allow predictions of left-right and long-short putting errors, we found they may be predictors of the golfers ability to consistently aim accurately. These results suggest that an unstable fixation disparity is associated with *inconsistent* spatial perception errors rather than a specific type of perceptual error either long/short or right/left. When Fronk and Coffey were not able to predict a specific putting error from the type of fixation disparity measured, they concluded that subjects must have learned to compensate for the consistent perceptual error present in their visual systems. However, if the fixation disparity is not stable, the golfer receives inconsistent visual spatial information. Therefore, golfers with an unstable fixation disparity would be expected to make greater aim errors because no compensation can be learned from inconsistent visual information.

The laser apparatus used to determine the objective aim measurement is new to the field of golf research. Therefore, it is important to note that a significant relationship was found between objective aim and left/right end-point putt error. This suggests that in this study putter face alignment was a predictor of putt endpoint error and this method of measuring putter face alignment may be a valuable tool in future investigations of this type. Also, since the Sheedy distance Disparometer is presently not widely available to clinicians, it is important to note the presence of a significant positive relationship between fixation disparity and associated phoria using the AO vectographic slide. This relationship suggests that the AO vectographic slide may be a useful tool for clinicians interested in spatial perception among golfers.

Although we have addressed some variables which affect putting performance, golf putting remains a very complex process that is affected by many additional variables that are difficult to monitor such as wind, varying conditions of the green, noise, stroke dynamics and other factors. The laser system enabled us to measure the putter face alignment only when the golfer was aligning the putt, not at the time of impact. Therefore, if a golfer changed his/her putter alignment during the stroke it went undetected. These are factors that should be considered in future research on the effects of oculomotor status on performance of tasks which require spatial judgements.

What does this all mean to the vision care providers who are interested in testing and treatment of oculomotor tonus on task performance that requires spatial judgement? We have shown that fluctuations in fixation disparity result in less accurate aiming ability which in turn appears related to errors in task performance. Therefore, when designing a sports vision training or enhancement program fixation disparity testing should be included in the diagnostic testing battery to help identify inefficiencies in the visual system that contribute to errors in task performance. Athletes that exhibit a fixation disparity and/or an unstable fixation disparity may benefit from a vision enhancement program that includes specific training activities to decrease and/or stabilize the fixation disparity.

REFERENCES

Dowley, D., Fixation Disparity. *Optometry and Vision Science,* 66(2): 98-105,1989.

Ebenholtz, S.M. and Fisher, S.K., Distance adaptation depends upon the plasticity in the oculomotor control system. *Perception and Psychophysics,* 31(6): 551-560, 1982.

Ebenholtz, S.M. and Wolfson, D.M., Perceptual afteraffects of sustained convergence. *Perception and Psycophysics,* 17: 485-491,1975.

Fronk, K. and Coffey, B., Effect of oculomotor posture on spatial judgement in golf putting. Unpublished doctoral thesis, Pacific University College of Optometry, Forest Grove, OR, 1985.

Makini, H., Yamamoto, D., and Coffey, B., Errors in spatial judment associated with compensation of habitual fixation disparity. Unpublished doctoral thesis, Pacific University College of Optometry, Forest Grove, OR, 1987.

Paap, K.R. and Ebenholtz, S.M., Perceptual consequences of potentiation in the extreaocular muscles: An alternative explanation for adaptation to wedge prisms. *Journal of Experimental Psychology: Human Perception and Performance,* 457-468,1976.

Paap, K.R. and Ebenholtz, S.M., Concomitant direction and distance aftereffects of sustained convergence: A muscle potentation explanation for eye-epecific adaptation. *Perception and Psychophysics,* 21: 307-314, 1977.

Schor, C.M., The influence of rapid prism adaptation upon fixation disparity. *Vision Research,* 19: 757-765, 1979.

Schor, C.M., Fixation disparity: A steady-state error of disparity induced vergence. *American Journal of Optometry and Physiological Optics.* 57: 618-637, 1980.

Shebilske, W.L., Karmiohl, C.M., and Profit, D.R., Induced esophoric shifts in eye convergence and illusory distance in reduced and structured viewing conditions. *Experimental Psychology: Human Perception and Performance,* 9(2): 279-277, 1983.

Sheedy, J.E., Fixation disparity analysis of oculomotor imbalance. *American Journal of Optometry and Physical Optics*, 57: 632-639, 1980.

Yekta, A.A., Jenkins, T., and Pickwell, D., The Clinical Assessment of Binocular Vision Before and After A Working Day. *Ophthalmology and Physiological Optics,* 7(4): 349-352, 1987.

Yekta, A.A., Jenkins, T., and Pickwell, D., Binocular Vision without Visual Stress. *Optometry and Vision Science,* 66(12): 815-817, 1989

AIM AND ALIGNMENT RESEARCH

PORTLAND, OREGON

SEPTEMBER 5,6,7, 1988

NAME:_______________________________________ Player #____________

ADDRESS:____

PHONE:_________________________AGE:____________________________

MALE________FEMALE_______AMATEUR__________HNCP_________CLUB PRO______TOUR PRO_________

PLEASE RATE YOUR PUTTING ABILITY: 1= Very Poor, 10=Excellent ----______________

SHORT TO MID RANGE_______________ 20' AND LONGER______________________

DO YOU USUALLY MISS PUTTS? SHORT__________LONG_________RIGHT__________LEFT___________

EYE DOMINANCE - LEFT________________RIGHT______________________

<u>AIM BEFORE CORRECTION:</u>

PUTT #1______________ DEGREES R - L

PUTT #2______________DEGREES R - L

PUTT #3______________DEGREES R - L

<u>AFTER CORRECTION:</u>

PUTT #1____________DEGREES R - L

PUTT #2____________DEGREES R - L

PUTT #3____________DEGREES R - L

CORRECTION PROCEDURE

___________VIEWING ADJUSTMENT

___________INTERNAL ADJUSTMENT

PHORIA:

FIXATION DISPARITY:

VISUAL ACUITY:

Appendix 1. Entrance Questionaire

Subject Data: Royal Oaks Study 09/88

Name:

Visual Acuity OD 15 20 25 30 <30
OS 15 20 25 30 <30
OU 15 20 25 30 <30

Preferred eye: OD OS

25% 50% 75% 100%

Heterophoria SO XO Hyp Ph Tr

Associated phoria **PRE** Type
Magnitude ________
Stable Unstable

ODSO OSSO ODXO OSXO

Associated phoria **POST** Type
Magnitude ________
Stable Unstable

ODSO OSSO ODXO OSXO

Adaptation (2^) within 5 10 seconds Base out Y N Stable Unstable
5 10 seconds Base in Y N Stable Unstable

Fixation Disparity (Sheedy @ 4m) **PRE** ____ / ____ Stable Unstable

POST ____ / ____ Stable Unstable

Putting Error

	Dx	Angle	Quad		Dx	Angle	Quad
1.	____	____	____	1.	____	____	____
2.	____	____	____	2.	____	____	____
3.	____	____	____	3.	____	____	____
4.	____	____	____	4.	____	____	____
5.	____	____	____	5.	____	____	____
6.	____	____	____	6.	____	____	____
7.	____	____	____	7.	____	____	____
8.	____	____	____	8.	____	____	____
9.	____	____	____	9.	____	____	____
10.	____	____	____	10.	____	____	____

Appendix 2. Oculomotor Testing Recording Form

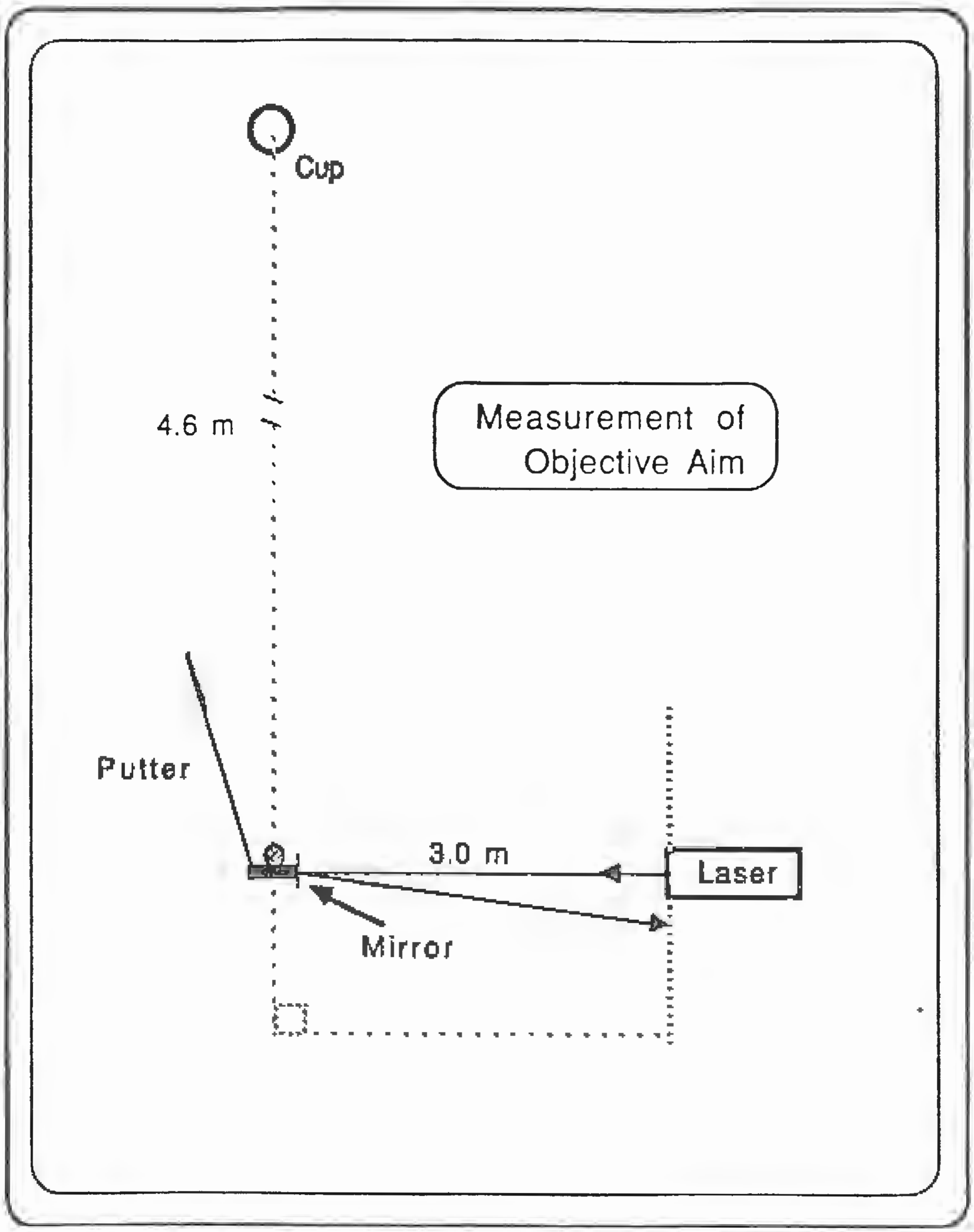
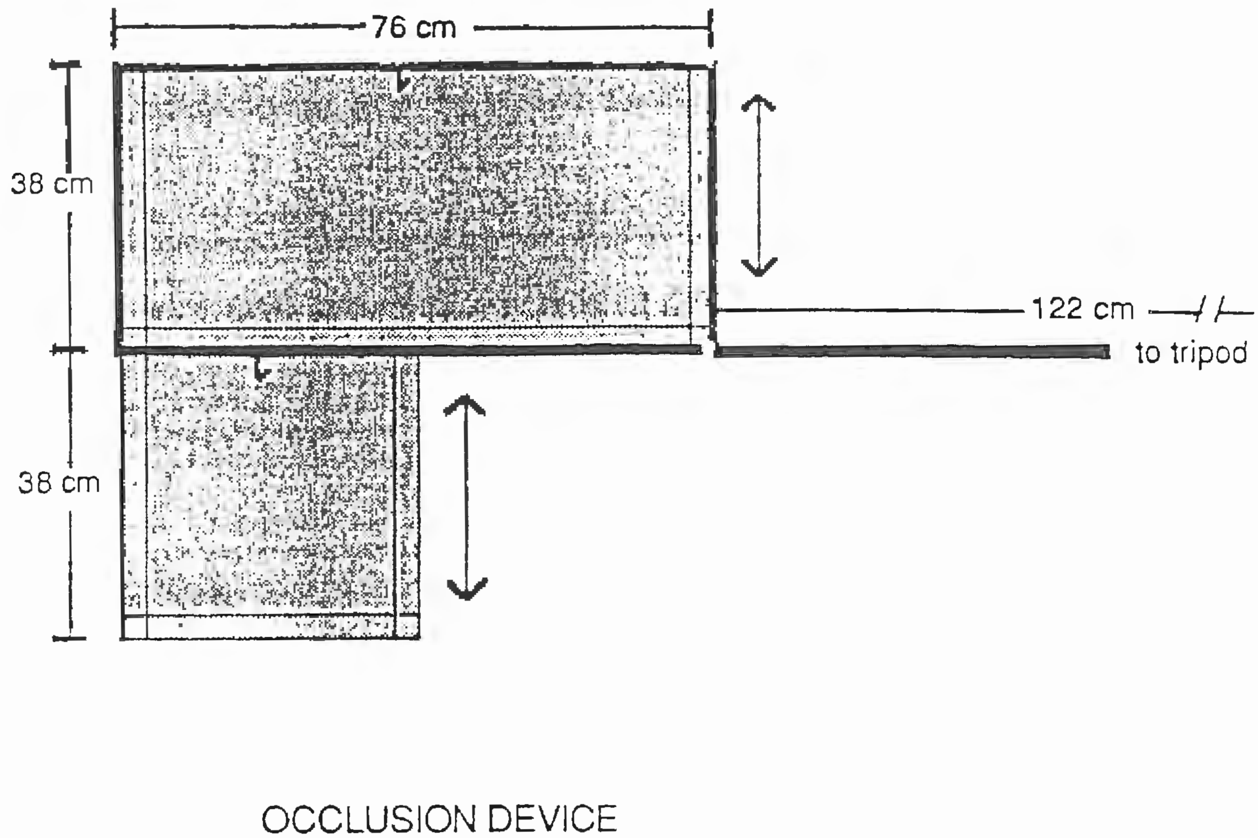
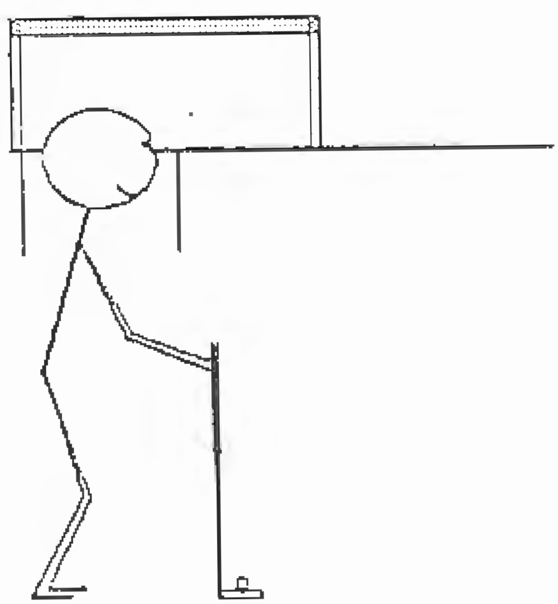


Figure 1. Schematic of laser apparatus used for measurement of objective aim, the direction in which the putter face is aimed just prior to beginning the putting stroke.

Figure 2. Schematic of the occlusion device used to deny visual feed back following the putt.





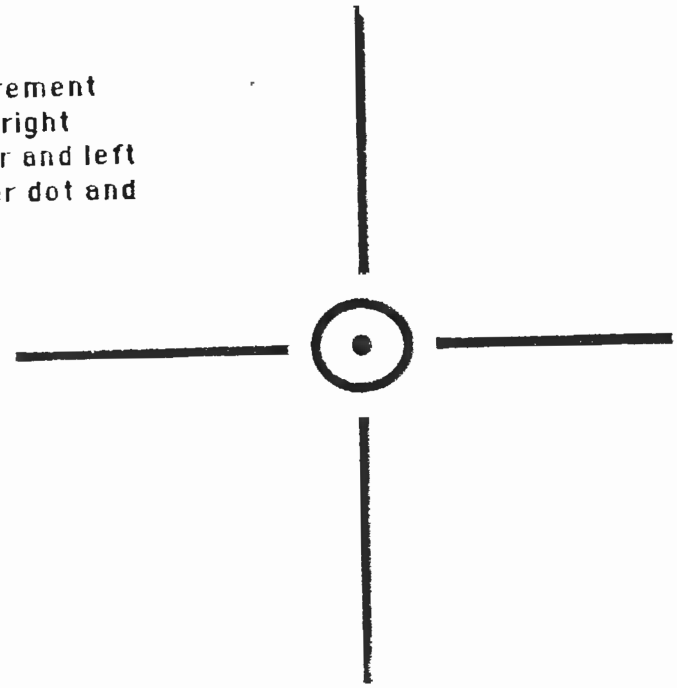


Figure 3. Target used for measurement of associated phoria. Upper and right lines are seen by right eye; lower and left lines are seen by left eye. Center dot and circle are seen by both eyes.

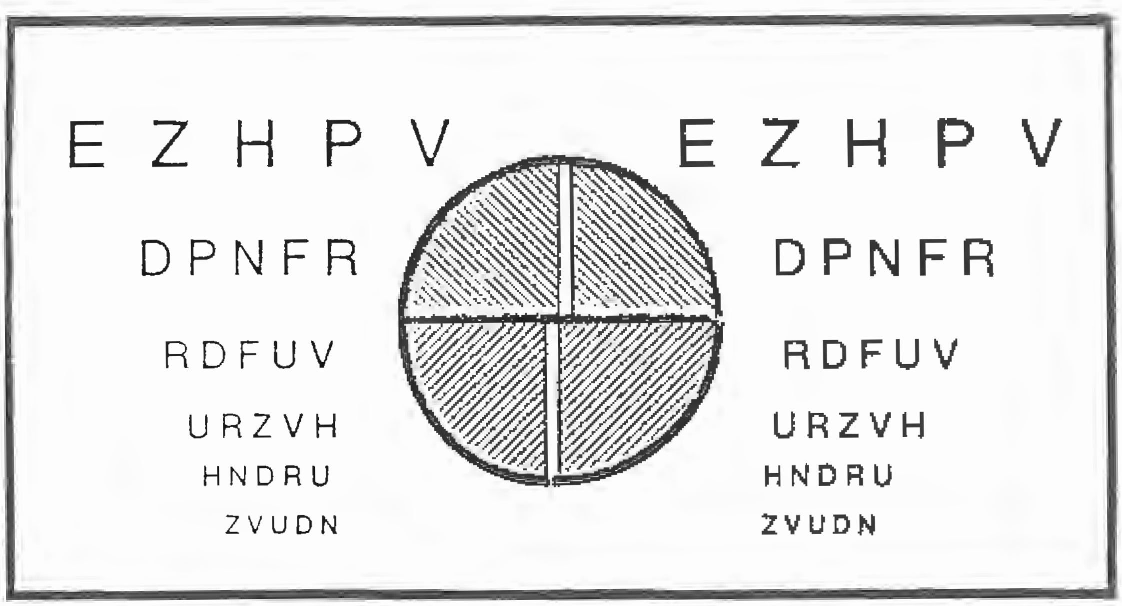


Figure 4. Face of Sheedy Distance Disparometer used to measure fixation disparity. Upper vernier line is seen by right eye, lower vernier line is seen by left eye. The upper vernier line may be adjusted left and right to a positior where the subject perceives alignment of the upper and lower verniers.

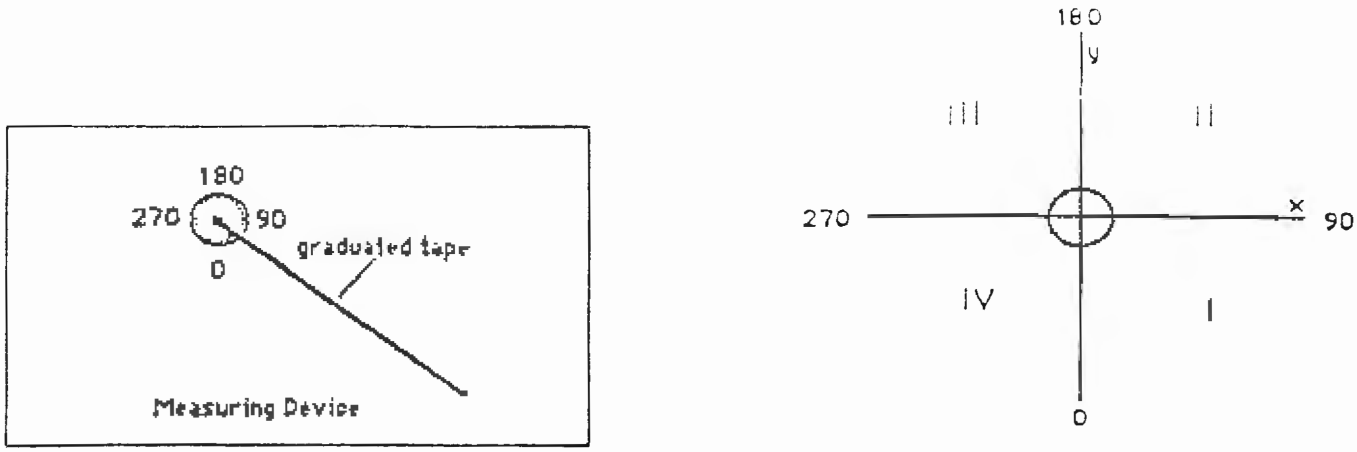


Figure 5. Schematic of the degree scale placed over the cup to measure distance error.

GENDER	AGE	HANDICAP
Female: 41 Male: 21	Range: 15-70 Mean: 51	Range: 0-24 Mean: 3.6
PUTTING ABILITY Range: 3-10 Mean: 6.8	**SHORT TO MID RANGE** Range: 4-10 Mean: 6.8	**20 ' AND LONGER** Range: 3-10 Mean: 6.6

Table 1. Summary of data collected from entrance questionaire.

VISUAL ACUITY			PREFERRED EYE
OD 20/15: 26 20/20: 26 20/25: 7 20/30: 0 <20/30: 3	OS 20/15: 33 20/20: 23 20/25: 1 20/30: 4 <20/30: 1	OU 20/15: 50 20/20: 10 20/25: 0 20/30: 0 <20/30: 2	OD: 34 OS: 29

ASSOCIATED PHORIA	PRISM ADAPTATION	FIXATION DISPARITY	HETEROPHORIA
Range: 5 eso-2 exo Mean: 0.89 PD	5 Seconds BO: 41 BI: 35 10 Seconds BO: 1 BI: 2	Range: 8.5 eso-3.4 exo Mean: 1 eso	Orthophoria: 4 Exophoria: 30 Hyperphoria: 8 Tropia: 0

Table 2. Summary of data collected from the oculomotor tests.

OBJECTIVE AIM CATAGORIES	MAGNITUDE & DIRECTION OF OBJECTIVE AIM	AIM ERROR CATAGORIES	MAGNITUDE OF AIM ERROR
Left Objective Aim	>3 cm to the left	Good	<5 cm
Right Objective Aim	>5 cm to the right	Poor	>5 cm
Straight	<3 cm to the left to >5 cm to the right		

Table 3. Comparison group catagories based on magnitude and directionality of Objective Aim and Aim Error

F.D. Mean Group	n	Subj Aim (cm)	Obj Aim (cm)	Aim Error SD (cm)	Putt Endpoint Error Dx (cm)
LOW (≤2 min arc)	31	3.1 ± 4.3	4.4 ±13.3	4.3 ± 3.1	11.9 ± 9.1
HIGH (>2 min arc)	30	2.8 ± 3.6	14.4 ±17.6	8.5 ± 7.6	17.6 ±12.3

Table 4. Differences among subjects when divided into subgroups based upon fixation disparity mean. Significant differences ($p<.05$) are highlighted.

F.D. Range Group	n	Subj. Aim (cm)	Obj. Aim S.D. (cm)	Aim Error S.D. (cm)	Putt Endpoint Dx Error (cm)
LOW (≤3 min arc)	26	3.7 ± 9.2	4.0 ± 1.8	4.3 ± 3.1	11.9 ±9.1
HIGH (>3 min arc)	35	10.0 ±18.2	6.1 ± 4.0	8.5 ± 7.6	17.6 ± 12.3

Table 5. Differences among subjects when divided into subgroups based upon fixation disparity range. Significant differences ($p<.05$) are highlighted

Assoc. Phoria Group	n	Subj. Aim (cm)	Obj. Aim (cm)	Aim Error (cm)	Endpoint Error (cm)
YES (>1 p. d.)	31	2.6 ± 4.5	8.9 ± 15.4	8.4 ± 15.3	10.2 ± 12.1
NO (≤1 p.d.)	27	3.4 ±3.6	5.2 ± 14.9	2.2 ± 15.1	6.7 ± 15.3

Table 6. Differences among subjects when divided into subgroups based upon associated phoria. Significant differences (p<.05) are highlighted.

Aim Error Group	n	Putt Endpt Dx Error (cm)	Putt Endpt LR Error (cm)
GOOD (≤5 cm)	24	10.5 ± 7.8	25.1 ± 14.1
POOR (>5 cm)	38	17.8 ± 12.3	35.2 ± 21.5

Table 7. Differences among subjects when divided into subgroups based upon aim error. Significant differences (p<.05) are highlighted.