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THE EFFECTIVENESS OF THE GOLF-LITE AS A PRACTICE DEVICE
ON LEARNING TO DRIVE A GOLF BALL STRAIGHT

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

by

Robert Eugene Gensemer, B.Sc., M.Sc.

* * * * *

The Ohio State University
1968

Approved by

D. K. Mathews
Adviser
Department of Physical Education
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VITA

December 9, 1936  Born - Denver, Pennsylvania

1961 .......... B.Sc., East Stroudsburg State College
East Stroudsburg, Pennsylvania

University, University Park, Pennsylvania

1962 .......... M.Sc., The Pennsylvania State University
University Park, Pennsylvania

Lancaster, Pennsylvania

1965-1967 .  .  .  Teaching Associate, The Ohio State
University, Columbus, Ohio

1967-1968 .  .  .  Assistant Professor, The University of
Denver, Denver, Colorado

PUBLICATIONS

"Measurement in Physical Education," The Ohio Athlete, pp. 21-23,
December 1967

FIELDS OF STUDY

Major Field: Physical Education

Physical Education. Dr. Donald K. Mathews and
Dr. Lewis A. Hess

Counseling. Dr. Lyle D. Schmidt
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CHAPTER I

INTRODUCTION AND DEFINITION OF TERMS

INTRODUCTION

Few other individual games are as theoretical as golf. Accepted methods to be employed by the participant in the driving of a golf ball have originated largely without scientific foundation. Those who have played and studied the game are quick to offer their empirical opinions as to the prescribed sequence of complicated movements which will most effectively place a small ball in a sometimes seemingly smaller hole in the least number of trials. The manifold conclusions of players and teachers of golf are not infrequently in disagreement, sometimes even diametrically opposed, and that is perhaps one of the many reasons why millions of people keep everlastingly at the game, grasping each new thought with the idea that somehow their own personal mystery of golf might be solved.

Reduced to its basic task, golf is simply a game of striking a ball with a club. Associated objectives of each player may be to strike the ball in a specific manner, or to impart a certain spin onto the ball, or to hit the ball a certain distance, or to swing the club in a defined fashion, or to look aesthetic while doing it, or a myriad of other objectives. Essentially, however, the golfer
wishes to strike the ball with the clubhead so that it will respond according to his intent. In the context of this primary concern the game of golf is resolved in the manner in which the clubhead meets and consequently causes motion of a stationary ball.

In driving a golf ball from a tee the golfer is essentially concerned with two objectives: (1) distance, and (2) accuracy. Obviously, a ball will respond only according to how it is struck. To achieve maximum distance in the drive the golfer must generate maximum clubhead speed. To achieve accuracy the clubhead must strike the ball in a specified position and move in a specified path while the clubhead and the ball are in direct contact. Inherent in the two objectives of distance and accuracy is the belief expressed by many golf authorities that the average player, often referred to as the "weekend golfer," should attend largely to the second objective: that of accuracy. This is particularly true of the drive, since resulting distance is greatest with this shot and consequently deviant ball flights are most magnified. In the words of Hogan:

If the wood shots go astray you could be the best iron player in the world, but you would have no real chance to prove it because you would be playing from out of the rough and bunkers or from behind trees all the time. Whereas, if your tee shots are controlled your iron play problems will be much simpler.¹

Any instruction given to beginning golfers which incorporates anything other than how to keep the ball in the playing area is, according to Armour, "... just one more thing for the pupil to remember, and one which won't help him." Seldom, however, does the weekend golfer follow such philosophy, but instead attempts the first objective: that of driving the ball its greatest distance, often sacrificing accuracy. To accomplish this the golfer must swing the clubhead fast. Boros criticizes such efforts:

To control a fast swing, which requires split-second hand action, a golfer must play often. The weekend golfer will have less trouble keeping a swinging (controlled) swing operable than he would an all-out power stroke.3

Emphasizing his belief that the average golfer all too often plays with the power and distance objective in mind, Demaret concludes that, "The weekend golfer is either the most fearless guy who ever lived--or he just doesn't know any better."4

In keeping with such opinions stated by professional golfers, the basic premise of this study is that the average or beginning golfer should indeed attempt to keep the ball in the fairway by driving it straight. Further, the beginning golfer should consider

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distance a lesser immediate objective, and, should make no attempt to intentionally cause the ball to slice, hook, or deviate in any other fashion from straight flight.

With the premise established, and within the limits of this study, the concern herein is one of how to best assist beginning golfers to pattern a swing which will result in straight ball flight. In this concern it is initially important to understand that, according to the laws of physics, in order to drive a golf ball into straight flight it is necessary for the center of mass of the clubhead to meet the ball directly behind (relative to the target) the center of mass of the ball. In addition, since the clubhead and the ball remain in contact for a brief but definite distance, it is also necessary, for straight flight to result, that the clubhead be travelling on the intended line of flight toward the target while in contact with the ball, and with the clubface squared (at right angles) to the target. Jones considers this to be the most important aspect of the golf swing.

The answer is certainly that when a straight flying shot is desired, the ideal condition is met if the club, when it makes contact with the ball, is moving precisely along the line of flight, with its face exactly square, or perpendicular, to the line of play. A deviation in either the alignment of the clubface or in the direction of its motion must tend to drive the ball off line, or to impart a sidespin which will cause it to curve in its path.\(^5\)

This is seemingly an anatomically impossible task, for a golfer swings the clubhead in an arc, not on a straight line. However, that arc tends to flatten as the clubhead moves through the hitting area, and approximates a straight line. Palmer describes this phenomenon:

... at the bottom of the golf swing, when you get into the hitting area, there is a distance of several inches where a combination of arm action and wrist action makes the clubhead travel in an almost perfectly straight line. In relation to the ground, the golf swing... shows the clubhead approaching the ball from the inside-out—that famous phrase again. Then for a brief instant, while the clubhead is whipping through the hitting area at its maximum speed, it straightens out. At the moment of impact, the clubhead is travelling—or should be travelling—in the exact same direction as the intended line of flight.  

If it were known exactly how long (in terms of distance) the clubhead and the ball are in actual contact, then it would also be known how long it is necessary for the clubhead to travel along the line of flight. The distance of actual contact is, however, a somewhat unanswered question. Early writers could only guess at the distance the clubhead moved forward while in contact with the ball. In 1932 Martin wrote: "It is reasonable to believe that the club is touching—or very nearly touching—the ball for a space of 6 to 8 inches, varying of course with the amount of

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sweeping force that is behind the blow." Morrison, in 1936, stated that the contact time was probably much less than that, but even in 1966 Bassler and Gibson were to state that, "At impact on the downswing, the clubhead and the ball remain in contact for about 2 inches." With the use of strobe lighting and high-speed film the distance of actual contact has been shown to be less than these estimates, but even sophisticated camera technology has not completely settled the issue. The earliest and one of the few published reports of strobe techniques applied to the contact of a clubhead and a golf ball is that by Edgerton and Killian in 1939. Although the authors do not state a definite distance in which the clubhead and the ball are touching, they do state that, "... the ball is off the club face when the face has advanced to a position over the center line of the tee." 

Owing largely to this lack of information concerning the contact between clubhead and ball, one of the purposes of this

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study was to investigate the characteristics of that contact. For this investigation a high-speed motion picture camera was used to photographically record the impact of a driver clubhead on a golf ball. To secure supplementary information concerning this investigation, letters of inquiry were sent to selected golf organizations who should conceivably have data about the characteristics of contact.

It was hypothesized that the filming would demonstrate if the clubhead does indeed travel a straight path while in the hitting area, and that it would also validate that straight ball flight is the result of a clubhead which is moving on the intended line of flight during contact with the ball.

Finally, with the hypothesis that, in order to achieve straight ball flight the golfer must swing the clubhead along the intended line of flight in the hitting area, this study was concerned in the main with assisting beginning golfers to develop a swing which would find the clubhead so travelling. As an aid to such effort this study has utilized a practice device called the Golf-lite, and subsequent investigation was made as to its effectiveness. The Golf-lite, briefly described, is an apparatus which attaches to the shaft of a golf club and, by means of a small battery-operated bulb, will leave a retinal after-image in

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11 Designed by Donald K. Mathews and Fred R. Johansen and Patented number 3,070,373 by Sports Teaching Aids, Inc., Columbus, Ohio.
the eyes of a golfer who swings the club in a darkened area, thus tracing for him the path of his clubhead through the hitting area.

STATEMENT OF PROBLEM

The purpose of this study was to determine the effectiveness of the Golf-lite when used as a practice device on the ability of beginning golfers to learn to drive a golf ball into straight flight. An underlying premise which has formed the basis of this study is that straight flight is possible only when the clubhead is travelling on a line toward the target while it is in direct contact with the ball. To investigate the validity of this premise, and to discover the distance of actual contact along with the speed of a driver clubhead before and after contact and the speed of the struck ball, this study has utilized high-speed motion picture photography to record and study these characteristics.

LIMITATIONS OF THE STUDY

This study was limited in its concern and findings to the full-swing while using a driver. Thirty undergraduate students at The University of Denver, Denver, Colorado, took part in the study as subjects. The photographic investigation was limited to the area several inches before, during, and several inches after contact.
SIGNIFICANCE OF THE STUDY

As golf continues its increasing popularity among the public and in school and college physical education classes the need for efficient means of teaching the skills involved also increases. Learning to hit a golf ball effectively involves the control of two main variables: distance and accuracy. This study is predicated on the premise that the beginning golfer should concern himself first with learning to hit the ball for accuracy. To learn accuracy the golfer must pattern a swing which finds the clubhead moving on a path toward the target when it makes contact with the ball. According to the laws of physics, this is the only way a golf ball can be driven into straight flight.

When a golfer swings a driver with the Golf-lite attached, and in a darkened area, the Golf-lite will leave a retinal afterimage, thus tracing very clearly for that golfer the path his clubhead took through the hitting area. The golfer therefore receives a visual feedback, which could in a very real sense be called error feedback.\(^\text{12}\) This is to say that if the clubhead does not move in a path toward the target while in the hitting area it constitutes an error, and the golfer can then readjust his swing on the basis of this visual feedback. Since it has been shown

\(^{12}\)Margaret Robb, "Feedback," *Quest*, VI (May, 1966), 38.
that the opportunity to view one's own performance, such as seeing films of oneself, will facilitate motor skill learning, and


18 ______, and D. Flanagan, "Film Loops Analyze Bowling Results," School Activities, XXIX (May, 1958), 297.


since it has been speculated that the inability to visually inspect the arms when they are drawn out of the frontal space field may interfere with skill development, and since it has been shown that immediate knowledge of results is beneficial to the acquisition of a motor skill, it was hypothesized that the visual feedback provided by the Golf-lite would assist the beginning golfer to pattern a swing which would move the clubhead in the desired path while in the hitting area.


This is not an investigation of teaching methods but rather of the effectiveness of a practice device. The significance of this study lies chiefly in the determination of whether or not the Golf-lite can be utilized as an aid which will assist beginning golfers in learning to hit a golf ball straight while using a driver. This is a kinesthetic sense purported in this study to be facilitated in its development by visual feedback.

DEFINITION OF TERMS

The following definitions refer to a right-handed golfer. Throughout the remainder of this study all discussions involving these definitions will be related to a right-handed golfer.

Line of flight. An imaginary straight line drawn from the ball to the intended target.

Inside-out swing. A clubhead path which, at impact, is moving across the line of flight away from the golfer.

Outside-in swing. A clubhead path which, at impact, is moving across the line of flight toward the golfer.

Open clubface. A clubface which, at impact, is at a right angle facing to the right of the line of flight.
Closed clubface. A clubface which, at impact, is at a right angle facing to the left of the line of flight.

Impact. The physical collision of the clubhead with the ball. The moment of first touching.

Contact. The duration of actual touching of the clubhead and the ball.

Slice. A ball hit with a clockwise spin causing it to curve sharply to the right in its flight.

Hook. A ball hit with a counter-clockwise spin causing it to curve sharply to the left in its flight.

Hitting area. The distance several inches before and extending to several inches beyond contact.

RELATED LITERATURE

In his comprehensive text on the history of golf, Browning credits Americans as being the first to scientifically analyze the game rather than merely imitating good golfers or at least assuming that they demonstrate the most effective methods for playing golf. In reality, however, true scientific research directly concerned

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with the hitting of a golf ball has appeared only within very recent years. Accepted techniques employed by golfers and by teachers of golf have had their origin in opinion or empirical observations. Among the most commonly accepted of these opinions are the supposed causes of slicing and hooking. Slicing, according to those who write about golf, is the result of: (1) a clubface which is open at impact, and/or (2) a clubhead which is drawn across the ball in an outside-in arc. Hooking, then, is the result of: (1) a clubface which is closed at impact and/or (2) a clubhead which is brought into the ball on an inside-out path.

To investigate the relationship of the path of the club-head through the ball to the flight characteristics of the struck ball, Guerrera filmed a professional golfer who attempted to hit four balls which would slice, four which would hook, and one straight drive. An overhead motion picture camera running at 128 frames per second recorded the clubhead path for each shot. Three of the four sliced balls were caused by a clubhead crossing the line of flight from outside-to-inside with the clubface closed. The fourth slice, the largest, was caused by an outside-to-inside path with an open clubface. Three of the four hooking balls were caused by a clubhead crossing the line of flight from inside-to-
outside with an open clubface. The fourth was a smothered hook caused by a clubhead moving outside-to-inside with a closed clubface. 33

Other research utilizing machine driven balls has shown that rotating the driver one sixty-fourth of an inch either direction will result in a drive that may carry 250 yards but will be 100 yards to one side of the target. 34

Further research with machine driven balls has demonstrated that straight flight is produced only when the clubhead is, at the moment of impact, moving in the direction of the target with a clubface square to that target. 35-38


34 Frank Walsh, "The Swing Clinic," Golfing, XVIX (March, 1950), 27.

35 Ibid.


38 F. P. Koehler, "How the Modern Ball Evolved," (article included in packet of materials forwarded by The National Golf Foundation, place of original publication unknown).
To teach beginning golfers to swing the clubhead on a line toward the target at impact, McDaniel performed an experiment, later published by Mathews and McDaniel, which utilized an earlier form of the Golf-lite as a practice device. To determine the effectiveness of the Golf-lite, subjects attempted to hit a target 150 yards away and 100 feet in diameter while using a five-iron. Seventy-three subjects were used, with thirty-three acting as an experimental group which practiced the swing with the Golf-lite attached to the club. At the end of nine weeks, with the classes meeting twice a week, the control group and the experimental group both made improvements in ability, but the experimental group improved significantly (P < .01) over the control group in the ability to hit the marked area with a five-iron.40 After the use of the earlier form of the Golf-lite in the study by McDaniel, the practice device was developed into the form used in the present study.

Practice devices for golfers are not new. They have appeared on the commercial market as early as 1927,41 but controlled research concerning their effectiveness is virtually non-existent.

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CHAPTER II

METHODS AND PROCEDURES

The purpose of this study was, first, to investigate the characteristics of contact between a driver clubhead and a golf ball, particularly the distance of actual touching. For this investigation a high-speed motion picture camera was used to photographically record the impact between a clubhead and a ball. As supplementary information to this investigation, letters of inquiry were sent to golf organizations requesting data about the characteristics of contact.

A second purpose of this study was to employ the Golf-lite as a practice device to assist beginning golfers in learning to swing a driver clubhead in a path that will drive a golf ball into straight flight. It has already been stated that to achieve straight flight the golfer must meet the ball with the clubhead travelling on a path toward the target. It was hypothesized that the Golf-lite would assist beginning golfers to do this, and that the photographic analysis would indicate the distance it was necessary for the clubhead to so travel.

Photographing procedures. To photographically record the impact between clubhead and ball on motion picture film it was necessary to use an ultra-high speed camera. The Department
of Photography at Ohio State University, which performed all the filming, made available a high-speed camera (a 16-mm. Fastex WF 3). It is a product of the Wollensak Optical Company, and is capable of running at speeds up to 7,600 frames per second when pulling 280 volts A.C. current. However, only a 120-volt outlet was available at the site of the filming. When pulling 120 volts the camera will run up to 4,400 frames per second. Once started, the camera will run its entire loading of film before it can be stopped. Because of loading space, the camera will use only one-hundred feet of film and, as explained, it will always run the entire one-hundred feet each time. The film is fed through the camera in one and one-third seconds.

When in operation, the camera requires time to build speed, and as a result it is running at its top speed only at the end of the film. Figure I on the following page presents a schematic representation of the film speed at various footages of the film.

Instead of a shutter, the image of the photographic field is cast onto the film by a multi-sided optical glass prism mounted in a housing located between the lens and the drive sprocket, and directly geared to the drive sprocket.

The speed of the film at any one point of the one-hundred feet can be calculated after the film is developed, due to the fact that the camera utilizes a timing device while filming. The timing device consists of a neon glow lamp enclosed in a small
SPEED OF CAMERA AT VARIOUS FOOTAGES OF THE FILM
housing mounted under the drive sprocket in the camera housing. The lamp is energized by A.C. surges and emits light focused on the edge of the film by a small lens. Lamp operations result in timing marks appearing about 2.5-mm. in width along one edge of the developed film outside of the picture area. The length of the mark on the exposed film will vary with the speed of the camera. Running from 120 volts the light produces 120 flashes per second, equivalent to a time interval of 0.00833 seconds between the start of successive flashes. The time interval between the start of each flash divided by the number of intervening frames will give the time between exposures. For example, if there are 33 frames between the start of two timing marks, and the number of frames is divided by the time interval, 0.00833, a camera speed of 3,962 frames per second is obtained. To determine the time interval between individual frames, the time between flashes, 0.00833, is divided by the number of frames between flashes, 33, to arrive at an interval of 0.00025 second.

Five one-hundred foot rolls of Eastman type 7278 reversal 16-mm. film were shot of the hitting area. Because of the speed with which the film runs through the camera, timing the start of the filming was difficult. It was hoped that the camera would be approaching its peak speed just as the clubhead contacted the ball. Examination of the developed film revealed
that the time of impact occurred when the camera was running at speeds of 2,763, 3,602, 3,962, 3,962, and 4,082 frames per second for each of the five trials.

The filming was done at the intramural fields of Ohio State University. The site was chosen because of the open space into which the balls could be hit and because of the easy access to a 120-volt A.C. outlet. In addition it was necessary to have the electrical outlet close to the filming area, since the camera will not run at its top speed for that current when more than 100 feet of extension line needs to be used. For the filming at the intramural fields, only 60 feet of extension line was used.

The intent of this filming was to allow a study of the clubhead and ball interaction when the ball is driven into straight flight. Deviant flight patterns and their causes were not a concern. Therefore, it was imperative that a skilled golfer should drive the five balls for the filming. Mr. Roderick Myers, coach of the Ohio State University golf team and a former touring amateur golfer, consented to hit the balls.

New Titlist Acushnet balls, with a compression rating of 90, were used during the filming. A compression rating of 90 is by far the most common and popular for amateur golfers.

The balls were hit during a cloudless summer day between the hours of 1 and 2 P.M. There was no wind, and the temperature,
which does affect the compression and resulting flight of the ball, was 82 to 84 degrees during the filming.

Of the five rolls of film taken, three were shot from directly above the tee, while the remaining two were shot from ground level. For the overhead filming the camera was mounted to a track judges stand with C-clamps. The mounting placed the camera nine feet above the ground, with the lens aimed at about five degrees from the vertical toward the tee. For the ground level filming the camera was placed on an expanding stand nine feet from the tee. The stand raised the camera lens one and one-half feet from the ground.

To measure the clubhead and ball speed, and the length of distance and time of actual clubhead and ball contact (on the developed film), a grid was drawn with black india ink on a dull green surface, then placed under the tee for the overhead and beside the tee for the ground-level filming. The grid was marked off in five millimeter sections both horizontally and vertically. Length of the grid was 300 millimeters with the width 220 millimeters. However, the photographic field incorporated only 280 millimeters (11 inches) of length and 180 millimeters (7 inches) of width. To facilitate more

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accurate measurement a section in the center of the grid 120 millimeters in length was marked off with lines one millimeter apart. When filming both the overhead and ground level shots the ball was placed so that its back edge rested at the beginning of the section marked off in one millimeter widths since it was in this area, when the clubhead and ball are in actual contact, that the most precise measurements needed to be taken. In the developed film the lines spaced one millimeter apart appear slightly out-of-focus, although they can be distinguished. The lines marking the grid off in five millimeter sections were drawn heavier on the grid and as a result are clearly seen.

For the overhead filming the grid was secured to the ground with golf tees. A section was cut out of the grid for placement of the tee from which the balls would be hit. It was sufficient length to allow the tee to leave the ground freely after contact without disturbing the grid. Since the filming was done on a day with bright sunshine, the ball and the grid were placed so that the shadow cast by the ball would fall directly below and slightly to the side, with the hopes that the shadow would aid in the measurements taken. As a result, when viewing the developed film, the shadow does indeed aid in determining when the clubhead and ball are, or are not, in actual contact.

Circumstances of the ground level filming mandated
that the camera be placed behind the golfer with the lens focused on the ball through the golfer's legs. This was necessitated because of the availability of the electrical outlets. All the outlets were located on the east side of the intramural fields, so the balls had to be hit in a northwest direction to allow the shadow of the ball to fall on the grid as explained. If the camera were placed in front of the golfer, because of the position of the sun, the ball would likely appear on the developed film as merely a shadow and measurements would be difficult. The camera was better placed, therefore, behind the golfer so that the sun would fall on the side of the ball and the clubhead facing the camera. This did, in the developed film, allow for clear measurements to be taken. The grid was held upright during the ground-level filming, and on the opposite side of the ball to allow freedom for the clubhead to pass the grid.

Since the speed of the film could easily be calculated, measurements could be made from the developed film which revealed the following: (1) the speed of the clubhead before contact, (2) the speed of the clubhead after contact, (3) the speed of the ball after contact, (4) the length of time and distance of actual clubhead and ball contact, and (5) the path of the clubhead before and after contact. To make these measurements the developed film was run through a viewer and stopped frame-
by-frame for examination when the clubhead entered the photographic field. The film actually seemed to appear in more detail when run through a viewer than when shown on a screen frame-by-frame, thus the viewer was utilized for the measurements.

**Inquiry to manufacturers of golf equipment.** In order to better understand the characteristics of clubhead and ball behavior in the drive, letters of inquiry were sent to eighteen organizations who either manufacture or should conceivably have information about golf research. Information was requested concerning (1) the specifications of manufacture of the driver and ball, (2) typical driver clubhead speeds before contact, (3) typical driver clubhead speeds after contact, (4) the length of time and distance of actual clubhead and ball contact, (5) typical ball speed after contact, (6) the amount and characteristics of ball deformation at contact, and (7) the causes of straight and deviant ball flight patterns.

Of the eighteen letters mailed to the various organizations, thirteen companies responded. Several organizations indicated that they either did not have information readily available or that they did not wish to divulge it. Those so indicating were Hillerich and Bradsby Company of Louisville, Kentucky, Plymouth Golf Ball Company

The subjects in the study. The subjects used in this study were thirty undergraduate students from The University of Denver. All were enrolled in two beginning golf classes offered as part of the required physical education program.

The subjects ranged in age from eighteen to twenty-five. Of the thirty, eleven had never played golf on a regulation course, nine had played less than five rounds of regulation golf, seven had played between five and ten rounds, while three had played between ten and twenty rounds. Only those who had never played golf, or who had played but not scored below 100 for eighteen holes were permitted to register for the classes. It might be well to indicate that, in the opinion of the writer, the skill level of the thirty subjects was, with four or five exceptions, rather low.
The class sessions. The classes were scheduled to meet at 12 noon and 1:00 three times weekly for the ten-week spring quarter at The University of Denver. Final exam scheduling and two holidays which fell on the days of the golf classes limited the total number of class sessions to twenty-seven. Of these twenty-seven class meetings, practice with the Golf-lite occurred in only eighteen. During the nine sessions in which the Golf-lite was not used, three were devoted to orientation and basic fundamentals without swinging practice (stance, grip, etc.), four class sessions were forced indoors because of rain, one was devoted to skill evaluation, and one was used for administration of a written examination. In addition to the regularly scheduled class sessions, all subjects met on a par-3 course with the instructor twice during the quarter, and played nine holes each time. A brief overview of the class-by-class instruction is presented in the appendix.

The testing sessions. Between the third and the fourth class sessions, and between the twenty-fifth and the twenty-sixth class sessions, all subjects performed in a skill test designed to measure the golfer's ability to hit a ball into a designated area while using a driver. The literature revealed various methods of testing the ability to drive a
golf ball, some using cotton or plastic balls rather than regulation balls, but most utilizing a marked area into which the subjects attempted to drive the balls. In some cases, the skill test credited the performer with a score when the ball bounced or rolled into the marked area in addition to balls which landed on a fly in that area.

To use the vernacular, it was concluded that, if one wished to discover the ability of subjects to drive a golf ball straight, then the test should be designed so that, simply, it allowed subjects to drive a golf ball toward a target. All that was necessary, then, was to designate an area and count the number of balls the subject could hit into that area while using a driver. This is indeed a simple test, but a valid one, since it is a true representation of driving ability.

It was determined that no subject should receive credit for a ball which bounced or rolled into the designated area, but only for those balls which hit in the area from flight. Therefore, the terrain of the testing area would have no effect on the results of the test.

The area chosen for testing was the Wellshire Municipal Golf Course. The choice was made because of its location being near The University of Denver campus allowing easy access for the subjects, and, because the management of the course allowed
the use of the driving range for the testing purposes at half
the normal fee for driving golf balls.

The driving range at Wellshire faces a lake into which
the balls are hit. This was of no concern since it had been
previously determined that only those balls which would land
from the fly into the designated area would be counted as
scores. To mark the area the management of the driving range
placed two flotation markers one hundred and fifty feet apart
and each one hundred and seventy-five yards from the spot where
the subjects would stand. This was to approximate the width
of a typical fairway, and to place the area far enough away
from the golfer so that only solid hits would enter that area.

By standing directly in back of the subject taking the
test, the writer was easily able to determine whether the ball
hit the area or not. To be counted as a score, the subject
had to drive the ball at least one hundred and seventy-five
yards on the fly and keep it within the confines of the two
flotation markers. However, the ball was counted as a score
if it landed within two imaginary lines drawn from the tee,
through the flotation markers, and extending technically to
infinity. Therefore, since these imaginary lines moved
away from each other as the distance from the golfer increased,
the further the golfer hit the ball, the more the area increased
in width.
Each of the thirty subjects was assigned a particular time during a two-day interval in which he would take the initial skill test, and again during a two-day interval for the second testing. With two exceptions, only one subject performed the test at any one time.

Each subject was given thirty balls to hit, using only a driver. The first five were not counted but were considered as a warm-up. Of the next twenty-five, each drive which hit in the marked area was counted, and the total number of balls reaching that area was recorded. This same procedure was employed for both the initial and the post-testing sessions.

**Grouping of subjects.** After the initial testing session, the thirty subjects were paired, matching one subject's score with another subject's as closely as could be done. This procedure, done in rank order from the lowest to the highest score, set the thirty subjects into two groups of fifteen each, and matched the groups in initial ability. As it turned out, both groups had identical mean scores and similar standard deviations, making the assumption of matched groups tenable.

After matching the groups, one group was assigned as the control group, which would not be given the experimental condition (practice with the Golf-lite), while the other group was designated as the experimental group and would use the
experimental condition. This assignment designated six members of the class meeting at noon as subjects of the control group, with nine as members of the experimental group. The class meeting at 1:00 had nine members of the control group and six members of the experimental group.

The fact that the classes had subjects of both the control and experimental groups present in the same class tended to hold constant any variable in instruction given to the classes, since all were therefore exposed to the same discussions, and since both classes followed the same lesson plan on the same days.

**Description of the Golf-lite.** The Golf-lite is essentially a battery and flashlight bulb enclosed in a barrel-shaped plastic case. The apparatus is just under five inches in length and weighs about three and one-half ounces. It attaches to the shaft of a golf club by use of a clamp and wing-nut assembly. Attachment is always at the lowermost part of the shaft.

To operate, the Golf-lite utilizes the principle of centrifugal force. When a club with the apparatus is swung even at minimal speed, the weight of the battery (a 4.2-volt mercury cell) depresses a small spring to make contact with the bulb. A beam of light is then cast through a lens and
reflects on the floor about the size of a dime. Thus, when the club is swung in a darkened area, the Golf-lite will trace the path of the clubhead on the floor with a beam of light. This, then, creates enough of an after-image in the eyes of the subject so that his clubhead path through the hitting area is quite distinguishable to him.

**Use of the Golf-lite.** A closed room under the stadium at The University of Denver was chosen as the area for the experimental group subjects to practice the swing with the Golf-lite attached to a driver. The stadium room was only a one-hundred-foot walk from the outdoor class area, could be darkened when the lights were turned off, and was large enough to permit four golfers to swing freely at the same time without interfering with one another.

Strips of white athletic tape one-half inch in width and twenty-four inches in length were placed on the floor. Another strip of tape three inches in length was placed so it intersected the twenty-four inch strip at the middle of its length. When the subjects swung the lighted clubhead, they were instructed to address themselves relative to the tape, that is, so that the twenty-four inch length of tape would represent the intended line of flight while the intersecting smaller strip would represent the ball and the contact area.
The subjects then attempted to swing the clubhead so that the beam cast by the Golf-lite would travel along the line of flight, particularly at contact.

The Golf-lites were attached to the shaft of the club so that the beam of light would be cast directly beneath the sole of the clubhead. During the preliminary experimentation the apparatus was aimed at the perpendicular. Several faculty members who served as subjects during this preliminary testing expressed the opinion that the Golf-lite should be aimed in the direction of the shaft so that the beam of light would fall beneath the clubhead.

Beginning with the fourth class session the experimental group subjects began spending ten minutes each class in the darkened room practicing the swing with the Golf-lite attached. The subjects were always sent to the practice area by the writer, never more than four at one time. This was deemed a better procedure than allowing them to go at any time during the class session, since it was imperative that any group instruction given to the class as a whole needed to have all class members present. Should this not have been the case, the exposure to golf instruction would have been different for members of the experimental group, adding a variable to the study not statistically controllable. At no time was group instruction given while any subjects were at the indoor area.
With ten minute sessions, and eighteen class days, the total time of practice with the Golf-lite by each experimental group subject was 180 minutes.

Loss of subjects. Originally, the study included sixteen subjects in each group. One subject, a member of the control group, was dismissed from the University in the eighth week of the quarter, while the other subject, a member of the experimental group, dropped the class in the second week. Both had initial test scores of zero.

Factors which may have affected performance. Learning to swing a golf club is a precise skill. The Golf-lite, when attached to the shaft of the club, added another one-fourth of the club's weight. This may have been enough of a change to cause the subjects to swing in a slightly different fashion than they would without the attachment of the apparatus. However, only one subject ever stated that he was bothered by the additional weight.

For ten minutes of every class session the experimental group subjects were not with the outdoor class, so it is conceivable that, in the final analysis, these subjects could have received less individual instruction.
ANALYSIS OF THE DATA

Analysis of the photographic data. The grid used in the filming was marked off in millimeters while Table I on page 39 presents the speed of the clubhead and the ball in feet per second. To convert millimeters to feet per second the following procedure was used. With the fifth film taken as the example, it was calculated that at the time of impact the camera was operating at 4,082 frames per second. When examining the developed film the clubhead was seen to be moving at exactly eleven millimeters per frame before impact. Multiplying the speed of the camera and the movement of the clubhead per frame gave the result that the clubhead was moving at 44,902 millimeters per second before impact. One millimeter is equal to .03937 inch, so the speed of the clubhead in millimeters per second was multiplied by .03937 to provide the speed in inches per second: 1,767.79174. Dividing this figure by twelve gave the clubhead speed in feet per second before impact: 147.3.

Movement of the clubhead on the developed film was at times variable. For example, in the fifth film, the clubhead moved through the pre-impact area at exactly eleven millimeters each frame, but in the second film the clubhead was seen to move at sometimes less than twelve and sometimes at more than thirteen
millimeters per frame. In such case, the total distance the clubhead moved was divided by the number of frames the clubhead is in view before impact to arrive at the speed. This figure was then rounded to the nearest one-half millimeter for calculation purposes. Such interpolation led to duplicate results in both film number three and four. The camera speed in both cases was also identical.

Average clubhead speed for the five trials was 148.7 feet per second before impact, and dropped off to 110.9 feet per second after contact. The ball was driven off at an average speed of 216.8 feet per second. Little variability is seen among the five filmings.

The time and distance of actual contact between the clubhead and ball was difficult to examine. Despite the fact that the camera was running at very high speeds during the filming, it apparently was not fast enough to record a complete study of ball compression and contact characteristics. Nevertheless, two conclusions can be drawn. First, in none of the films is the ball seen to be in contact with the clubhead for more than two frames, and only in the first film, when the camera was running at only 2,763 frames per second, is the ball in contact with the clubhead for just one frame. Therefore, since two frames average in time (for the five films) between 0.0004 and 0.0005 seconds to appear on a screen, it can be concluded that the
actual time of contact is around 0.0004 and 0.0005 seconds. Second, close examination of the contact between clubhead and ball indicates that the ball is moved forward never less than fifteen nor more than twenty-five millimeters while touching the clubhead. Thus, distance of contact is somewhere between 0.58 and 0.98 inches.

Before the golfer hit the balls an arbitrary target was chosen which was judged to be on the intended line of flight relative to the placement of the grid. The golfer then attempted to drive each of the five balls into straight flight toward that target. Table I demonstrates that, for all practical purposes, this was done. However, several characteristics of the clubhead path and ball flight might be noted.

In film number two the ball was seen to be driven off the heel of the club. As a result of this impact the toe of the club makes a violent counter-clockwise turn. In the last frame in which the clubhead is in full view it can be measured that the clubhead has been twisted 25° from the squared position it held at impact. The fourth film also shows the toe of the club to make a counter-clockwise turn after contact, although not nearly as great. This, too, is probably a result of the ball being hit from the heel, but it cannot be seen since the fourth film was taken at ground level and the position of the ball on the clubface as either being toward the heel or the toe cannot be determined.
In the second film it is interesting to note that the club approaches the ball from an inside-out path, and the face of the driver is squared at impact. According to the photographic study of Guerrera this should produce a hooked ball, but instead the shot resulted in a slight fade. The reasons for this can only be speculated. It must first be pointed out that the golfer in the Guerrera study was hitting with the expressed purpose of causing deviant flight patterns. Then, in the present study, what may have caused the fade is that, since the ball was hit off the heel, the clubhead may have rotated around the ball during actual contact. Although the clubhead can be clearly seen to rotate after contact, it is difficult to determine if that rotation was taking place during the time the ball and clubhead were touching. Assuming that it did, however, the rotated clubface would cause the ball to leave with a clockwise spin, resulting in the fade. This clockwise spin would come about because the ball, even though it is hit toward the heel, is essentially driven straight (in terms of force applied). With the clubface pulled around toward the ball, the side of the ball toward the toe will remain in contact longer. As long as there is contact, there is friction, and this friction will resist 

TABLE I
RESULTS OF FILM ANALYSIS SHOWING CLUBHEAD AND BALL SPEEDS THROUGH THE HITTING AREA FOR FIVE SEPARATE HITS WITH DRIVER

<table>
<thead>
<tr>
<th>Drive number</th>
<th>Film speed at contact in frames per sec.</th>
<th>Clubhead speed before contact in feet per sec.</th>
<th>Clubhead speed after contact in feet per sec.</th>
<th>Ball speed from contact in feet per sec.</th>
<th>Characteristics of the drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2,763</td>
<td>149.6</td>
<td>113.3</td>
<td>222.1</td>
<td>Straight</td>
</tr>
<tr>
<td>2</td>
<td>3,602</td>
<td>147.7</td>
<td>112.3</td>
<td>218.6</td>
<td>Fade</td>
</tr>
<tr>
<td>3</td>
<td>3,962</td>
<td>149.5</td>
<td>110.5</td>
<td>214.5</td>
<td>Slight fade</td>
</tr>
<tr>
<td>4</td>
<td>3,962</td>
<td>149.5</td>
<td>110.5</td>
<td>214.5</td>
<td>Slight draw</td>
</tr>
<tr>
<td>5</td>
<td>4,082</td>
<td>147.3</td>
<td>107.9</td>
<td>214.3</td>
<td>Straight</td>
</tr>
<tr>
<td>Average</td>
<td>3,674</td>
<td>148.7</td>
<td>110.9</td>
<td>216.8</td>
<td></td>
</tr>
</tbody>
</table>


the ball from turning any direction other than clockwise, thus resulting in the slight fade.

In all three of the overhead filmings the clubhead moves toward the ball from an inside-out path. However, in the first and the third films the clubhead appears to be moving on a line toward the target at the moment of impact. The clubhead continues on this line for a considerable distance after contact. In the first film the clubhead appears to travel toward the target in a straight line and directly in back of the path taken by the ball for 105 millimeters (4.13 inches) after contact, only then to move off the path toward the golfer. In the third film the clubhead is seen to move in a straight path behind the ball and toward the target for 190 millimeters (7.48 inches) after contact. In the second film the clubhead strikes the ball in an inside-out path and continues on that path after contact.

Of course the clubhead path is not shown in the ground-level films, but one interesting observation is the fifth film which shows the ball to be hit high, toward the top of the clubface. This causes the face of the club to lay back with the back of the club dropping toward the ground. This appears to occur after the ball has been sent on its way. At the time of the filming no note was made that this particular shot was hit any higher into the air than any of the other drives, which
might have been a logical conclusion after one would observe this film.

Analysis of data from subjects. This study was concerned with the influence of the Golf-lite on learning of the ability to drive a golf ball straight. Two groups of subjects were involved, one a control group which did not practice with the aid of the Golf-lite, another the experimental group which did. The outcomes of the study were recorded in the number of balls the subjects hit into a designated area with a driver.

The mean performance for each group could be found and the difference between the means could be tested for significance by the t or F-tests. However, the structure of the experiment provides for the application of a more sophisticated measure, the analysis of variance. Not the least of the allowances which the analysis of variance makes is for the limited number of subjects. With small groups such as used in this study, the proper statistical procedure is to employ a variance, since it will more accurately determine if true significance exists. The limited number of subjects also makes it somewhat less tenable to assume that they represent the total population, and that the groupings are perfectly equated in initial ability, even though they are statistically comparable with respect to initial test scores. The analysis of variance allows for a larger error in these two respects.
Tables II and III on pages 43 and 44 present the results of the two testings of the control and experimental groups. The subjects are ranked from lowest to highest by the scores each made on the pre-test. The number listed under each of the two tests for each of the two groups is the total number of balls out of a possible 25 that each subject hit into the designated area. It will be recalled that the initial testing session, listed on the tables as the pre-test, occurred before the subjects were divided into two groups and before any subjects had practiced with the aid of the Golf-lite. The post-test occurred after the experimental group and been administered the experimental condition: practice with the Golf-lite.

Initial means for the two groups are identical: 5.8. The standard deviations are similar: 4.9 for the control group and 5.0 for the experimental group.

In the analysis required for these kinds of data, since there are two groups (a control and an experimental) and a pre-test and a post-test, the experiment is particularly appropriate for application of an analysis of variance. A simple procedure to determine significance would be to utilize a t-test between trials within groups and compare the control and experimental group results on the pre-test and the post-test. Such comparisons among means are inappropriate because the subjects are not randomly selected, but instead the design
TABLE II
PRE-TEST AND POST-TEST RESULTS FOR THE CONTROL GROUP

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pre-test</th>
<th>$x^2$</th>
<th>Post-test</th>
<th>$x^2$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>36</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>G</td>
<td>4</td>
<td>16</td>
<td>6</td>
<td>36</td>
<td>10</td>
</tr>
<tr>
<td>H</td>
<td>4</td>
<td>16</td>
<td>10</td>
<td>100</td>
<td>14</td>
</tr>
<tr>
<td>I</td>
<td>6</td>
<td>36</td>
<td>14</td>
<td>196</td>
<td>20</td>
</tr>
<tr>
<td>J</td>
<td>6</td>
<td>36</td>
<td>7</td>
<td>49</td>
<td>13</td>
</tr>
<tr>
<td>K</td>
<td>10</td>
<td>100</td>
<td>15</td>
<td>225</td>
<td>25</td>
</tr>
<tr>
<td>L</td>
<td>10</td>
<td>100</td>
<td>12</td>
<td>144</td>
<td>22</td>
</tr>
<tr>
<td>M</td>
<td>12</td>
<td>144</td>
<td>20</td>
<td>400</td>
<td>32</td>
</tr>
<tr>
<td>N</td>
<td>14</td>
<td>196</td>
<td>11</td>
<td>121</td>
<td>25</td>
</tr>
<tr>
<td>O</td>
<td>15</td>
<td>225</td>
<td>15</td>
<td>225</td>
<td>30</td>
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<tr>
<td>Totals</td>
<td>87</td>
<td>879</td>
<td>131</td>
<td>1591</td>
<td>218</td>
</tr>
</tbody>
</table>

Means: Pre-test - 5.8, Post-test - 8.7

Standard deviations: Pre-test - 4.9, Post-test - 5.5
### TABLE III

PRE-TEST AND POST-TEST RESULTS FOR THE EXPERIMENTAL GROUP

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pre-test</th>
<th>$X^2$</th>
<th>Post-test</th>
<th>$X^2$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>36</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>144</td>
<td>13</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td>G</td>
<td>4</td>
<td>16</td>
<td>8</td>
<td>64</td>
<td>12</td>
</tr>
<tr>
<td>H</td>
<td>4</td>
<td>16</td>
<td>11</td>
<td>121</td>
<td>15</td>
</tr>
<tr>
<td>I</td>
<td>6</td>
<td>36</td>
<td>10</td>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>J</td>
<td>6</td>
<td>36</td>
<td>8</td>
<td>64</td>
<td>14</td>
</tr>
<tr>
<td>K</td>
<td>8</td>
<td>64</td>
<td>13</td>
<td>169</td>
<td>21</td>
</tr>
<tr>
<td>L</td>
<td>11</td>
<td>121</td>
<td>9</td>
<td>81</td>
<td>20</td>
</tr>
<tr>
<td>M</td>
<td>12</td>
<td>144</td>
<td>14</td>
<td>196</td>
<td>26</td>
</tr>
<tr>
<td>N</td>
<td>12</td>
<td>144</td>
<td>14</td>
<td>196</td>
<td>26</td>
</tr>
<tr>
<td>O</td>
<td>17</td>
<td>299</td>
<td>13</td>
<td>169</td>
<td>30</td>
</tr>
<tr>
<td>Totals</td>
<td>87</td>
<td>889</td>
<td>149</td>
<td>1601</td>
<td>236</td>
</tr>
</tbody>
</table>

Means: Pre-test - 5.8, Post-test - 9.9

Standard deviations: Pre-test - 5.0, Post-test - 2.9
of the experiment was to test groups that are randomly selected. The probability of obtaining a significant $t$, because of the selection of groups at random rather than subjects at random, would be considerably above what actually exists. The chance of accepting a false hypothesis is therefore higher than if the results are submitted to an analysis of variance. The $t$-test utilizes a smaller number of degrees of freedom to make comparisons and a less refined error term for such comparisons. In addition the analysis of variance has the potential of assessing an interaction between the groups and the testings which indeed can possibly occur. Since the actual hypothesis underlying this study is that the experimental group will show an improvement greater than the control group over the two testings, the hypothesis is examined by an interaction between the groups and the testings through an analysis of variance. This could not be determined in any refined sense by a $t$-test.

The small groups used in this study also makes the assumption that they represent the total population somewhat less tenable. The analysis of variance allows, through a refined error, for the possibility that the groups are atypical. A direct illustration of the analysis used in this study is found in Edwards.

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A presentation of the data from this study is given in Table IV on page 47. What was found was that when dealing with the two groups overall there is no significant difference between the groups. The F-ratio, which is a test for comparing variances, is not significant.

The analysis was actually run based upon the subjects in the same groups to test the between groups difference. There are, of course, appropriate degrees of freedom. Dividing the sums of squares by the corresponding degrees of freedom gives a variance estimate for mean square. The mean square has been placed over the error of mean square (between subjects in the same group) to obtain an F-ratio. The F-ratio is then checked in the appropriate table for significance at the .05 or .01 percent level.

In dealing with the within subjects analysis the component is between testings, since the same subjects are involved in each test. The F-ratio here (56.75) is significant beyond the .01 level. The pre-test and post-test, therefore, are significantly different, allowing the conclusion that actual learning of golf skill did take place for both groups.

The problem now is, does the experimental procedure show itself to be superior to the control procedure? The interaction (groups by testings) demonstrates that it is not so. The F-ratio of 1.63 indicates that there is no meaningful
### TABLE IV

RESULTS OF ANALYSIS OF VARIANCE
BETWEEN GROUPS AND WITHIN GROUPS

<table>
<thead>
<tr>
<th>Source</th>
<th>Sums of squares</th>
<th>df</th>
<th>Mean sums of squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>5.40</td>
<td>1</td>
<td>5.40</td>
<td>P = &lt; .01</td>
</tr>
<tr>
<td>Between subjects in same groups</td>
<td>1234.34</td>
<td>28</td>
<td>44.08</td>
<td></td>
</tr>
<tr>
<td>Total between subjects</td>
<td>1239.74</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between testings</td>
<td>187.26</td>
<td>1</td>
<td>187.26</td>
<td>56.75</td>
</tr>
<tr>
<td>Interactions:</td>
<td></td>
<td></td>
<td></td>
<td>P = &lt; .01</td>
</tr>
<tr>
<td>Groups by testings</td>
<td>5.40</td>
<td>1</td>
<td>5.40</td>
<td>1.63</td>
</tr>
<tr>
<td>Error (residual)</td>
<td>92.34</td>
<td>28</td>
<td>3.30</td>
<td>NS</td>
</tr>
<tr>
<td>Total within subjects</td>
<td>285.00</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1524.71</td>
<td>59</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
difference between the control and the experimental groups. The slightly greater improvement of the experimental group over the control group must therefore be attributed to the natural effects of practice, and the changes from pre-test to post-test are basically the same for each group.

**Discussion of results of experiment.** The control group in this experiment improved from a pre-test mean score of 5.8 to a post-test mean score of 8.7, while the experimental group improved from a pre-test mean score of 5.8 to a post-test mean score of 9.9. While the difference in improvements between groups is not statistically significant, the fact remains that the experimental group did improve more than the control group. Therefore, the use of the Golf-lite was by no means a hinderance to the learning of the skill of driving a golf ball, at least within the total picture of the group. The indication is that teachers of golf may wish to be selective in the students to whom they suggest practice with the Golf-lite, for the purpose of this practice device is to assist the golfer in developing a swing path which finds the clubhead moving along the line of flight toward the target at the moment of impact. Deviant ball flight patterns can result from two basic causes: (1) the path of the clubhead at the moment of impact, and (2) the angle of the clubface at the moment of impact. The Golf-lite is designed to, and indeed could only possibly correct
the first of these two causes of errant flight. Teachers of
golf should understand this. It leads to the implication
that if, for example, a golfer is bothered by a persistent
slice, and that slice is caused by an outside-to-inside
swing pattern, then the Golf-lite could and should be an
excellent device for assisting this golfer in rectifying the
problem. By contrast, if another golfer is also bothered by
a consistently slicing ball, and the Golf-lite shows his swing
to be along the line of flight, then further practice with the
device may be relatively unnecessary, since this slice is
probably due to an open clubface at contact. An excellent
example of this was subject 0 of the experimental group. In
the pre-test he scored a 17, the highest score of all thirty
subjects for that testing session. His swing path was on the
intended line of flight as shown by the Golf-lite. However,
in the course of the class sessions he began to develop a slice
which was the result of a slow right hand wrist action allowing
the clubface to be open at contact. His swing path remained
the same throughout the experiment, and he had now developed a
habit which the Golf-lite could not correct. In the post-test
the subject was able to score only a 13.

It might logically be concluded, therefore, that
within the confines of this experiment, the Golf-lite actually
did its purpose. It may have eliminated, or obstensibly reduced,
one of the two main causes of deviant ball flight, that of improper clubhead path at the moment of impact. This may account for the observed improvement of the experimental group over the control group. It is the opinion of the writer that this did happen; that the experimental group more so than the control group did indeed develop swing patterns which found the clubhead moving on a line toward the target at the moment of impact. This opinion must of necessity be qualified as merely emperical observation, however, and must stand as that only.

Opinions expressed by the subjects. At the conclusion of the study all members of the experimental group were asked to express their opinion as to the relative value of the Golf-lite as a practice device. None of the fifteen subjects indicated that they believed the device was without worth, although two stated that they felt it did not help them at all (one of the two scored lower on the post-test than the pre-test). Three subjects said they thought the time spent with the Golf-lite was boring compared to actually hitting balls. As already indicated, only one said he was bothered by the added weight, while two others stated they thought the added weight might actually be beneficial to, in effect, develop a better kinesthetic touch for the club. Four subjects pointed out a factor which is not an expressed function of the Golf-lite but may be an indirect value. They stated their
belief that it assisted them in keeping their head down during the swing and their eye on the ball rather than looking up and pulling away from the ball during the swing.

Comparison of photographic analysis with other data.
It will be recalled that letters requesting information about the speed of the club and ball, etc., were sent to organizations which were believed to have such information. The results of the photographic analysis made for this study will now be compared with the information that was received, along with information from other written sources including expressed opinions.

Strong has stated that photographic interpretations have shown a clubhead to be traveling as much as 70 MPH at impact (or about 103 feet per second). This may be a conservative conclusion, for Gustavson has indicated that professional golfer Betty Hicks could generate a driver clubhead speed of 86 MPH (126 feet per second) and an "above average" male could move the club at 120 MPH (176 feet per second) while a top pro would reach 146 MPH (213 feet per second).


These estimates for male golfers may also be unrealistic, for a photographic study made by A. G. Spalding & Bros. of professional Bobby Jones' swing showed he attained a driver clubhead speed of 138 feet per second, whereas another study made of Jones' swing showed his maximum clubhead speed to be 166 feet per second. McIntyre and Snyder studied the swings of twenty professionals and found speeds ranging from 60.5 to 104.0 MPH (89 to 153 feet per second) at impact, with the average at 82.9 MPH (122 feet per second). Harvey has stated that tests have revealed the average speed to be 162 feet per second. Tests performed at the True Temper Corporation revealed a similar result; that a "typical" professional golfer speeds the driver clubhead to about 160 feet per second.

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Other sources have agreed that an average professional will develop a clubhead speed of 160 feet per second, while the average amateur will generate a speed of only 145 feet per second. Information received from MacGregor states that an average clubhead speed for all golfers is 176 feet per second before contact, and Wilson Sporting Goods Company indicates that a "better than average" golfer will swing the driver at 203 feet per second. Calculations taken from the developed films shot as part of the research of this study revealed the clubhead to be moving at an average of 148.7 feet per second.

The distance that the clubhead and the ball are in actual contact is also given to varying data. Tests from the

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53 Letter from Terry Pocklington, Ram Golf Corporation, Pontiac, Mississippi, May 21, 1968.

54 F. P. Koehler, "How the Modern Ball Evolved" (article included in packet of materials forwarded by The National Golf Foundation, place of original publication unknown.).

55 Letter from Terry Pocklington.

56 Letter from D. A. Schierenbeck, MacGregor, Cincinnati, Ohio, May 16, 1968.

Spalding laboratory reported by Harvey show the length of contact to be .35 inch. Tests at the True Temper Corporation, Ram Corporation, and the Batelle Memorial Institute of Columbus, Ohio, all revealed the clubhead to move forward about .75 inch during the contact time, while information from Wilson Sporting Goods states .80 inch as the length of contact.

Measuring the length of contact from the developed films at Ohio State University was quite difficult because the film was not fast enough to allow finite calculations. However, it could be concluded that the distance of contact fell somewhere between .58 and .98 inches.

The actual time in which the clubhead and ball are touching is also subject to some discussion, but there is more general agreement about this aspect. True Temper and Ram Golf Corporation tests indicate the time may vary between

58 Harvey, loc. cit.
59 Letter from George Manning.
60 Letter from Terry Pocklington.
62 Letter from Tom Tully.
Kelly and Harvey both have stated the time of contact to be .0004 second. 65,66 MacGregor research shows that a 90 compression ball will stay on the clubface .0004 second while a 40 compression ball will have a clubhead contact time of .0006 second. 67 Tests at Battelle Memorial Institute have shown a clubhead to ball contact time of .000425 second. 68 Finally, research results from Wilson Sporting Goods indicate a contact time of .0005. 69 Analysis of the films taken as part of this study is difficult due, again, to the camera speed. As a general conclusion it may be stated that the time is probably no more than .0005 second.

Most investigations of clubhead speed have been concerned with the speed before contact and only the speed of the ball after contact. However, available results show that

63 Letter from George Manning.
64 Letter from Terry Pocklington.
66 Harvey, loc. cit.
67 Letter from D. A. Schierenbeck.
68 Simon, op. cit., p. 20.
69 Letter from Tom Tully.
the forward speed of the clubhead drops off sharply after striking the ball. The photographic studies of Bobby Jones' swing show a driver clubhead speed of 110 and 114 feet per second, \(^70,71\) after a pre-contact speed of 138 and 116 feet per second. Research results from the Ram Golf Corporation show the speed to be 110 feet per second, \(^72\) a fifty foot per second drop from the 160 found as the pre-contact speed. These figures are also stated by the True Temper Corporation. \(^73\) Harvey states that with a pre-contact clubhead speed of 162 feet per second, the clubhead is reduced to 125 feet per second after impact. \(^74\) An analysis of this study revealed that the clubhead speed was reduced to an average of 110.9 feet per second from an initial speed of 148.7 feet per second.

Studies of the speed of the ball after it is struck have varied somewhat. Cochran simply states that the speed

\(^{70}\) Bunn, loc. cit.

\(^{71}\) Edgerton and Killian, loc. cit.

\(^{72}\) Letter from Terry Pocklington.

\(^{73}\) Letter from George Manning.

\(^{74}\) Harvey, loc. cit.
is somewhat over 200 feet per second.\textsuperscript{75} Other sources have indicated an initial speed of 210 to 220 feet per second.\textsuperscript{76,77} Edgerton and Killian have shown that Bobby Jones sends the ball away at 225 feet per second with a driver.\textsuperscript{78} Research from the MacGregor laboratories has shown that the ball speed will vary between 205 and 264 feet per second.\textsuperscript{79} This is a strange figure since the United States Golf Association's rules forbid the manufacture of a ball which will achieve a speed of more than 250 feet per second when struck a controlled blow by a machine.\textsuperscript{80} Information from the True Temper Corporation has shown that the initial speed of the ball leaving the clubhead will be 230 feet per second.\textsuperscript{81} Research from Wilson Sporting

\textsuperscript{75} Alastair Cochran, "The Ballistics of Golf: Bad Shots," (Reprint of an article appearing in May, 1961 issue of \textit{Golf Digest}).

\textsuperscript{76}"Let Your Equipment do its Job," \textit{Golf Digest}, XV (March, 1964), 24-29.


\textsuperscript{78}Edgerton and Killian, \textit{op. cit.}, p. 61.

\textsuperscript{79}Letter from D. A. Schierenbeck.

\textsuperscript{80}Letter from George Vallentine, National Golf Foundation, Chicago, Illinois, May 14, 1968.

\textsuperscript{81}Letter from George Manning.
Goods, the Battelle Memorial Institute, and Kelly all agree that the ball will jump off the club at 233 feet per second. Harvey states 238 feet per second as the speed, while Ram Golf Corporation research has shown the ball to leave the clubhead at 240 feet per second. The films shot for this study have shown an average speed of 216.8 feet per second.

It was seen in analyzing the films that the first response of the golf ball as it leaves the clubhead is that of elongation. At impact the ball is depressed against the face of the club, the amount of deformation appearing to be about one-tenth of its width, and deforming symmetrically on both sides. Then, as the ball regains its shape, it experiences elongation even as it is leaving the clubface. This elongation appears to persist until the ball has left the photographic field, an area of about six inches. Galvano discusses the response of a struck golf ball:

82 Letter from Tom Tully.
83 Simon, op. cit., p. 20.
84 Kelly, loc. cit.
85 Harvey, loc. cit.
86 Letter from Terry Pocklington.
The ball depresses against the clubface and, for an instant, the clubhead and ball travel at the same rate of speed. Then the elasticity of the ball causes the ball to expand, thereby giving it a forward thrust.

The forward thrust is so great that, the ball, in its early flight, has little or no spin. As the force diminishes the ball begins to acquire an underspin, making it rise sharply and then dropping very quickly and stopping. 87

Examination of the ball response in the films demonstrates very clearly that the ball is rotating with backspin as it leaves the clubface. These revolutions have been measured at the Spalding laboratory at 4,800 per minute. 88 This spin is always backspin, for it is impossible to hit a drive with overspin (that is, if the ball is squarely struck). In fact, the maximum amount of rotation occurs at the instant when the ball leaves the clubface, and thereafter, in flight, it decreases. 89

It has been shown that some sliding and rolling of the ball takes place during contact of the clubhead and the ball. 90, 91 Because of the speed of the camera being too slow, it was not possible to determine if this happened from the films taken for this study.

88 Harvey, loc. cit.
90 Simon, op. cit., p. 31.
91 Cochran, Impact, loc. cit.
CHAPTER IV

SUMMARY AND CONCLUSIONS

SUMMARY

The purpose of this study was to determine the effectiveness of the Golf-lite when used as a practice device on the learning of the skill of driving a golf ball into straight flight. An associated purpose was to utilize a high-speed motion picture camera to record the characteristics of clubhead and ball impact.

This study incorporated the use of the Golf-lite as a practice device to assist beginning golfers in the learning of the ability to drive a golf ball straight. Thirty subjects took part in a pre-test in which they attempted to drive balls into a designated area 175 yards away and 150 feet in width at its closest distance to the golfer. The number of balls out of 25 drives which entered the area from flight was recorded. The subjects were then split into two matched groups. One, a control group, attended instructional beginning golf classes for a period of ten weeks, three times per week. The other subjects were designated as the experimental group. They attended the same classes and were exposed to the same class procedures, but in
addition practiced with the Golf-lite attached to the shaft of a driver for eighteen of the class periods, ten minutes each time. Practice was held in a darkened room, where subjects attempted to swing the clubhead in a path that would find the light cast by the Golf-lite travelling along a strip of tape placed on the floor to represent the line of flight.

Near the close of the ten week period a second testing session was held, using the same procedures. The data collected from the two testings were then submitted to an analysis of variance for statistical interpretation.

It was found that both the control and the experimental groups made significant (beyond the .01 level) improvement from the pre-test to the post-test. However, while the experimental group did show more improvement from the pre-test to the post-test than did the control group, the difference was not statistically significant. Therefore, this improvement must be ascribed to the natural effects of practice, and, for all practical purposes the two groups did not demonstrate any meaningful difference.

To examine the characteristics of actual clubhead and ball contact, high-speed 16 mm. motion pictures were taken of the hitting area while a skilled golfer hit five golf balls.
With the camera speed averaging nearly 4,000 frames per second, three overhead shots and two ground level shots were taken with a grid marked off in millimeters as background. The grid allowed for easy discovery of the clubhead speed before and after contact, and for the speed of the struck ball. However, despite the speed at which the camera was running, it was still not fast enough for a precise measurement of the time and distance of actual contact between clubhead and ball.
CONCLUSIONS

Within the limitations of this study the following conclusions are drawn:

1. Improvement in the ability of the subjects to drive a golf ball into a designated area could not be attributed directly to the use of the Golf-lite as a practice device.

2. The Golf-lite cannot correct deviant ball flight patterns which are the result of an open or closed clubface at contact.

3. Research is quite varied concerning the driver clubhead speed before and after contact with a ball, the speed of the struck ball, and the length and time of clubhead and ball contact.

4. A struck golf ball deforms symmetrically about one-tenth of its width, and experiences elongation as it leaves the clubface.

SUGGESTIONS FOR FURTHER RESEARCH

To more carefully examine the characteristics of clubhead and ball contact, a camera with a greater speed than the one used in this study must be employed.

Replication of the experiment involving the Golf-lite using much larger groups may be a valid investigation, for the
same results found in this study, with larger groups, may prove to be statistically significant.

More research on the Golf-lite might involve increased practice time with the device.
## OUTLINE OF CLASS INSTRUCTIONAL TOPICS

<table>
<thead>
<tr>
<th>Class Session</th>
<th>Area of Instruction</th>
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<tbody>
<tr>
<td>2.</td>
<td>Demonstration and discussion of three basic grips: overlapping, interlocking, and full-finger. Discussion of stance.</td>
</tr>
<tr>
<td>6.</td>
<td>Indoor class due to rain. Explanation of terms, typical golf course layout, club selection as to situation, beginning discussion of rules.</td>
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<tr>
<td>7.</td>
<td>Withdrawal of clubhead on line from target, hitting on line toward target, follow-through.</td>
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<tr>
<td>8.</td>
<td>Weight shift throughout the swing.</td>
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<tr>
<td>11.</td>
<td>Waggle and forward press.</td>
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<tr>
<td>13.</td>
<td>Use of the irons. Review changes in stance according to the iron and intended distance.</td>
</tr>
</tbody>
</table>

15. Indoor class due to rain. Putting: styles, approach, and reading the green. National Golf Foundation film, "Putting."


18. Review of putting styles.

19-25. These seven class sessions contained essentially no new material. Each student practiced the shot and with the club of their choice. All class sessions devoted to individual instruction.


27. Written final examination.

Note - Between the fifteenth and the twenty-fifth class session all students met twice with the writer in groups of three or four at a par-3 golf course and played nine holes of golf each time.
BIBLIOGRAPHY

A. BOOKS


B. PERIODICALS


_____. "Slow Motion Moving Pictures Improve Swimming Techniques." *School Athletics*, XXXII (April, 1961), 233-234.


C. ARTICLES IN COLLECTIONS


_______. "The Ballistics of Golf: Impact." Reprint of an article appearing in March, 1961 issue of *Golf Digest*, forwarded as part of a collection of articles from The National Golf Foundation.

Koehler, F. P. "How the Modern Ball Evolved." Article included in collection of materials forwarded by National Golf Foundation, place of original publication unknown.


D. UNPUBLISHED SOURCES


E. OTHER SOURCES

Pocklington, Terry. Letter of May 21, 1968 to author.
Schierenbeck, D. A. Letter of May 16, 1968 to author.
Vallentine, George. Letter of May 14, 1968 to author.