ADVANCED CUE UTILIZATION OF SOCCER GOALKEEPERS DURING PENALTY KICKS

by

Tod Hanvey

B.P.E., The University of British Columbia, 1992
B.Ed., The University of British Columbia, 1998

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF HUMAN KINETICS

THE FACULTY OF GRADUATE STUDIES

School of Human Kinetics

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

April 1999

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Human Kinetics

The University of British Columbia
Vancouver, Canada

Date April 29, 1999.

DE-6 (2/88)

ABSTRACT

Two separate experiments were conducted to investigate the role of anticipation during the penalty kick in soccer. Experiment I examined the ability of experienced soccer coaches to anticipate the direction of the ball during a penalty kick. The subjects were randomly placed into either a control or experimental group. Each subject viewed 100 video simulations of penalty kicks during which reaction time, movement time, and response accuracy were assessed. The experimental group was instructed to recognize a single, reliable "advanced response" cue which would allow them to predict shot location more accurately than the control group. Both groups viewed 100 additional video simulations and the three same measures were compared to the results from the first 100 trials. Results indicated that the experimental group displayed a significantly higher response accuracy in the second set of trials, while the control groups' performance did not change significantly. This study demonstrated that an ability to recognize valid and reliable, advanced response cues leads to a greater prediction accuracy of shot direction.

Experiment II was designed as a visual training program intended to improve soccer goalkeepers' performance during the penalty kick situation. Eight expert goalkeepers were first assessed on their ability to stop penalty kicks in an actual field setting. The subjects were then visually trained to recognize a reliable, advanced response cue which would allow them to more accurately predict the direction of the penalty shot. The program was designed to reduce the time goalkeepers spend identifying response cues and decrease their response time to a level where they could consistently predict the direction of the ball. The goalkeepers were then given a post-training assessment of their shot stopping ability, to determine if the visual training transferred to improved penalty kick performance. Results indicated that subjects improved their ability to predict shot direction through the utilization of the response cue, "placement of the non-kicking foot". Subjects ability to predict shot direction increased significantly during the laboratory training. This increased predictive ability was also evident in both the transfer task and the post-training assessment during the penalty kick situation.

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENT

There are many people I would like to thank for their roles in helping me to complete this thesis. My advisor, Dr. Richard Mosher, involved me with the U.B.C. soccer program and this environment inspired me to pursue an applied, soccer investigation. Dr. Mosher also contributed greatly to this project with soccer knowledge and expertise that were always provided in a kind and patient fashion. I would like to thank my other committee members: Dr. Craig Chamberlin, for his constructive advice, participation and understanding through the different phases of this research.

I would also like to individually thank Dr. Ian Franks who played an integral role in this research from the beginning. Dr. Franks provided me with the setting to conduct what I hope is a quality research project. This study would never have been completed without his direction and support. Dr. Frank's firmness and adherence to high standards helped motivate me to work harder than I ever have in my life. I also greatly appreciate his patience and understanding over the past years.

Thanks to the motor control students, Tim McGarry, Mike Garry, Mike Kahn and Nicole Hodges whose advice and companionship were a great help during my time in the laboratory. I would especially like to thank Paul Nagelkerke for his expertise and humor during the many long hours of analysis.

I must also thank both my immediate and extended family for their unconditional support in all of my pursuits. For my mother, Sandra and father, Jack, who never stopped believing that I would finish this project. Who have never stopped believing in me.

Dedicated to Sarah,

For her unconditional love and support

and for always being there.

GENERAL INTRODUCTION

The importance of the penalty kick in deciding the outcome of soccer games has become increasingly evident in recent years. The results of international competitions, such as the FIFA World Cup Finals, have been decided by such "set plays." In fact, the penalty kick and the penalty kick shoot out were instrumental in deciding the outcomes of both the 1996 European Championships and the 1998 FIFA World Cup Finals. Within these situations, goalkeepers must make fast decisions followed by fast movement initiation and response. The penalty kick is a very short, discrete event in soccer games. The soccer ball is placed twelve yards from the goal line and penalty shot takers can shoot the ball at a velocity of more than a 100km/h. The entire event, from the initiation of the shot taker's movement to the ball crossing the goal line, takes less than two seconds. The severe time constraints involved in this situation make stopping a penalty kick a very difficult task for a soccer goalkeeper.

The difficulty of this task is due in part to the shot taker's fast approach to the ball. During this fast approach, the goalkeeper is required to search through a visually rich display and attend only to the information which will help them predict the direction of the shot. They must then interpret this information and initiate a horizontal movement intended to intercept the path of the ball. These tasks require goalkeepers to process a great deal of information during a very brief sequence. If goalkeepers are to make these accurate, fast decisions and responses in the short time frame available, goalkeepers must acquire information prior to ball contact in order to predict the intended direction of the shot. The ability of the goalkeeper in these situations is critical and efforts to improve their performance in these decision intensive situations needs to be made.

In order to help goalkeepers improve their performance in the penalty kick situation, a systematic analysis of all aspects of the penalty kick was conducted. This introductory analysis generated critical information that proved to be practically useful to a goalkeeper in improving their performance during the penalty kick situation. In our initial research into 138 penalties taken in FIFA World Cup competitions (1982 - 1994), it was evident that expert goalkeepers were not successful at predicting the direction of the penalty kick. Of the 138 penalties that were taken, 77.5 percent were goals, 8 percent of the shots missed the "target" and only 14.5 percent were saved by the goalkeeper. The goalkeepers reaction to these shots was even more significant. Correct prediction of shot direction was achieved on only 41 percent of all shots. These statistics clearly indicated that there is a need to improve the penalty kick performance of even the most expert goalkeepers. In order to be successful stopping penalty kicks, goalkeepers must improve their ability to search for reliable information in the shot taker's run up, make quick decisions or predictions on the direction and speed of the shot, and initiate their response to this prediction in time to intercept the path of the ball. Clearly, the speed with which they can accomplish these tasks is a determining factor towards successful shot stopping in the penalty kick situation.

This study is not the first research to investigate the penalty kick situation in soccer. There have been other researchers who recognized the difficult information processing task experienced by goalkeepers when facing penalty kicks. Most of these initial attempts to analyze the penalty kick have been very introductory in nature. For example, Kuhn (1988) examined strategies of both the goalkeeper and the shot taker in penalty kick situations. Kuhn suggested goalkeepers could improve their prediction performance by employing such strategies as studying the eyes of the shot taker or looking at how the shot taker's teammates line up around the 18 yard box. This research also suggested that goalkeepers could improve their shot stopping by waving their hands prior to the kick or lining up closer to one goal post than the other. This researcher did not report how these strategies were discovered nor did he investigate their usefulness in a systematic manner. Kuhn did, however, conduct a time-motion analysis of several German league penalty kicks and reported that the average time it took the ball to travel from contact to the goal line was 600ms.

Another part of our initial investigation was to conduct a more detailed performance analysis of the 138 World Cup penalty kicks we had compiled on videotape. We first defined an approximate time line of events for the penalty kick. This analysis supported Kuhn's results, that the average time from ball contact to the ball crossing the goal line was slightly less than 600ms. The movement time of the goalkeepers, which was defined as the time from first movement to the time for any part of the goalkeepers' body to cross the path of the ball, ranged from 500 to 700ms. Since this goalkeeper movement time is approximately equivalent to the time of ball flight, it follows that goalkeepers must begin their response before or at the same time as ball contact.

Given that reaction time for correctly anticipated events can range from 80ms (Higgins and Angel, 1970) to 144ms (Schmidt and Gordon, 1977) it is clear that goalkeepers should make the decision to move approximately 100ms prior to ball contact. On the other hand, if goalkeepers move too early they will not benefit from any late anticipatory response cues provided by the "penalty taker."

Further results from this analysis indicated that moving too early was not an effective strategy. During 64 of the 138 penalties taken in recent World Cup competition, goalkeepers moved before the kick was taken and only predicted correctly on 39 percent of these shots. When goalkeepers move early, only two strategies seem possible. The goalkeepers are either merely guessing the direction of the kick or attending to very early cues in the shot taker's approach to the ball. These statistics indicate that neither strategy is particularly successful. While attending to these earlier occurring cues allows the goalkeepers time to respond, these statistics show that these cues do not lead to an accurate response. Our analysis will present research which indicates that the closer a cue is to impact, the more reliable that cue is. Response cues which occur early in the pre-contact sequence can be disguised by a skilled shot taker. Therefore, it is critical for goalkeepers to identify a reliable response cue that allows them to predict and respond correctly.

The 41 percent accuracy displayed by the World Cup goalkeepers in our analysis clearly indicated that even expert goalkeepers are not effective at recognizing reliable response cues in order to accurately predict shot direction. However, research on anticipation and prediction in other sports (Jones & Miles, 1978; Salmela and Fiorito, 1979; Abernathy and Russell, 1984; Starkes , 1987) has revealed that expert performers have demonstrated skillful abilities to anticipate or predict event outcomes. Generally, these expert sport performers are effective at anticipation because they utilize valid response cues to enhance their predictive ability. We proposed that a goalkeeper's ability to anticipate ball direction during a penalty kick would improve if they could recognize valid, advanced response information. These response cues in the penalty kick situation were defined as information from the shot taker, prior to ball contact, which would allow a goalkeeper to successfully predict (significantly better than chance) the direction of the ball.

The ability to anticipate event probabilities through the utilization of advanced response cues represent a critical characteristic of the skilled or expert sport performer. Players in sports must continually process information about positions of opposing players and the speed and direction of an oncoming ball if they are to perform skillfully. Abernathy (1987) states, "...because of the speed at which many of these sports are played, much of the information processing must occur in advance of critical events such as ball flight..." Good anticipation skills are a prerequisite for successful performance in sports which are played at a fast pace with anticipation defined as the ability of an individual to successfully predict the outcomes of important events.

Research has shown that differences in the ability to anticipate exist between expert and novice participants in many different sports. Jones and Miles (1978) presented one of the first examinations of anticipation in skilled sport performance. These researchers developed a task in which subjects were shown film sequences of an elite player's tennis serve from the perspective of an opponent. Jones and Miles developed a film occlusion paradigm which provided tennis coach subjects with varying amounts of view time in the film display. Subjects were instructed to predict to which of three areas in the service court the ball would land. Results obtained demonstrated differences between the prediction performances of skilled and novice coaches only during the condition where advanced, pre-contact information was available to the subjects. Expert subjects were better able to use pre-flight information to accurately predict the direction of the serve. The film occlusion paradigm developed in this early study has since been applied to numerous sports. Despite a wide range of occlusion times, subjects, and response measures, all of these studies revealed the value of advanced cues to the response selection process.

In a study which examined the role of anticipation in hockey, Salmela and Fiorito (1979) investigated the abilities of 34 young ice hockey goalies to anticipate the direction of shots. These researchers occluded their film display 8, 4 and 2 frames (250 ms to 50ms) prior to puck contact. Results indicated that the prediction performance of the goalies was aided by the increased availability of advanced cues. The most accurate responses were obtained when subjects viewed the video display occluded 2 frames (60ms) prior to contact. The results of this study support the contention of our research that the closer a cue is to impact, the greater predictive value it has.

A study conducted by Abernathy and Russell (1984) investigated expert and novice cricketers' ability to anticipate the direction and length of a bowled cricket ball. All subjects viewed film sequences occluded at the point of ball release. Greater predictive abilities of the experienced subject group supported the view that anticipatory skill is a function of expertise. Expert subjects in this cricket study were able to predict the length and direction of a cricket ball far better than the novice group of subjects. Abernathy and Russell concluded that these experts were extracting reliable information from the bowler's run up to more accurately predict the flight of the ball. This is a similar task to the one faced by soccer goalkeepers in the penalty kick situation. The success rate of the goalkeepers in our initial analysis would indicate that they are not picking up reliable cues in the pre-contact sequence. This Abernathy and Russell study, however, indicated that it is possible for expert performers to extract such information in a brief time period such as a penalty taker's approach to the soccer ball.

Another study which investigated the role of expertise on anticipatory ability was conducted by Starkes (1987). This researcher examined the ability of national, varsity and non players to anticipate the direction of a penalty flick in field hockey. Results indicated that only the prediction performance of the group of national level players exceeded chance when the display was occluded prior to contact. This research is particularly relevant to the present discussion because its methods, subject base, and task closely parallel our investigation. The Starkes' study used film representations of the field hockey penalty flick which initiated with the penalty taker's first movement and were occluded (cut off) just prior to impact. The researchers asked the subjects to orally predict to which area of the net the ball was being directed. Again, the group of national level players which were able to predict shot direction better than chance were able to attend to cues from the penalty taker. Starkes study provides further support that many expert sport performers have a superior ability to anticipate events in their sport domains. These data also indicates that one of the reasons for the poor prediction performance of our expert goalkeepers is due to the fact that they are not attending to reliable response cues in the penalty taker's approach to the ball.

Research that has specifically investigated the penalty kick situation in soccer has examined the relationship between anticipation and the penalty kick. McMorris, Copemam, Corcoran, Saunders, and Potter (1993) investigated the ability of 10 experienced university goalkeepers to anticipate the direction of the penalty kick, viewed from a dynamic film display. The temporal occlusion paradigm was utilized with the tape being cut off both before and after impact. Results indicated that the condition of occlusion after impact created fewer response errors but there was no significant difference between occlusions at and prior to impact. The design of this study and the usefulness of the results obtained can be questioned. It seems obvious that the occlusion point after impact, which gave ball flight information, resulted in a rather simplistic predictive task. This study is also limited by the fact that the researchers did not discuss which advanced cues the subjects attempted to use in the earlier occlusion conditions. The inability of researchers to determine the most valid or pertinent response information was a limitation of most of the previous anticipation studies that have been reported here.

Therefore, the next phase of our investigation was designed to discover what the most valid or reliable response cues in the pre-contact sequence of the penalty kick were. This analysis progressed towards Experiment I which was designed to test the reliability of the response cue which we determined to be the most accurate predictor of shot direction in the penalty kick situation.

EXPERIMENT I - INTRODUCTION

There has been some other research which has attempted to investigate the use of response cues and anticipation in soccer. Williams and Burwitz (1993) sought to examine the effect of playing experience on the ability to anticipate ball direction during the penalty kick. Film was occluded 120ms before impact, 40ms before impact, at impact and 40ms after ball impact. Thirty experienced and 30 inexperienced soccer players viewed a video simulation of a penalty kick taken from the perspective of the goalkeeper. Researchers measured response accuracy and the results indicated that experienced players were better able to use earlier occurring cues to more accurately predict shot direction. The results confirmed that it was possible to anticipate ball direction from the preparatory movements of the penalty taker. Subjects were then asked to report which cues they used to predict shot direction. The use of verbalizations of experienced athletes represents an important, early step in attempting to discover the most valid, pre-contact response information. However, these researchers used self reports of field players and not goalkeepers to discover the important response cues. More importantly, this study's search for advanced cues was not very in depth. The researchers made no attempt to systematically determine which pre-contact cue(s) would allow for the most accurate prediction of the direction of the penalty kick.

The initial analysis we conducted on the World Cup penalty kicks also revealed that there is information prior to ball impact which should allow a goalkeeper to more accurately predict the direction of a penalty kick. Both the McMorris et al. (1993) and the Williams and Burwitz (1993) studies represent preliminary research on the ability of goalkeepers to anticipate ball direction during a penalty kick. It was evident from this research that the information gained prior to ball contact was important for accurate shot prediction. No research to date has systematically investigated which are the most valid, pre-contact cues that would allow a goalkeeper to correctly anticipate ball direction.

Consequently, the next step in the analysis was to identify all the response cues that were displayed by the penalty taker prior to ball contact and calculate the reliability of these response cues to predict shot direction. The following cues were identified in chronological order: The "penalty takers" - starting position, angle of approach to the ball, forward or backward lean of the trunk, placement of the non-kicking foot, inward or outward knee rotation of the kicking leg just prior to contact, and the point of contact on the ball.

For practical reasons reliable prediction was set at 80 percent (Rushall, 1977) and response cues were considered independently. We felt that on the occasions when prediction from an early cue was incongruent with a later one, the time taken to disconfirm the first cue would inflate reaction time, thereby causing the goalkeeper to move after ball contact. Moving after ball contact would consistently result in the goalkeeper being too slow to intercept the path of the ball.

Whereas the later response cues were able to predict shot direction with an accuracy of more than 80 percent, early cues such as the starting position of the penalty taker, angle of approach and lean of trunk all fell below acceptable limits of reliability (80 percent). While attention to these early cues would give the goalkeeper sufficient time to react, experienced outfield players can disguise early cues or confuse the goalkeeper into making an incorrect prediction. The closer a response cue is to the end of the penalty taker's approach to the ball, the more reliable a predictor of shot direction it is. However, the time constraints associated with the later cues call into question their utility.

For example, the cue "point of ball contact" was close to 98 percent accurate, but if the goalkeepers were to wait until they had identified this cue before initiating movement they would be late by at least 100ms. The cue "point of ball contact" can only be identified 10ms prior to ball contact. If the goalkeeper then takes 100ms to predict the direction of the ball and close to 500ms to initiate and perform their diving movement, they would consistently be too slow to intercept the path of the ball. A similar scenario would exist for the cue "knee rotation of the kicking leg."

The only response cue investigated in our performance analysis that was both reliable and time efficient was **the placement of the non-kicking foot**. This cue was 80 percent reliable and allowed goalkeepers between 150 and 200 ms to react after detection. In other words, the placement of the foot occurs 150 to 200 ms prior to the penalty taker contacting the ball. The position of the foot appears to dictate the direction of the shot. If the foot is directed toward the right, then the shot will be to the right. Similarly, if the foot points to the left the shot is directed to the left. On the few occasions when the foot is pointing towards the center of the goal, two outcomes seem most likely. Either the ball will be driven directly at the goalkeeper or the ball will be driven to the goalkeeper's right (or left for a left-footed shot taker).

The final phase of our initial analysis on the penalty kick involved confirming that this response cue was the most reliable and efficient information to help goalkeepers accurately predict shot direction. The reliability of this response cue over the other cues in the shot taker's approach to the ball was investigated by separating each cue in the sequence. Each cue was investigated individually by the researchers occluding all the information except for the one cue as the shot taker approached the ball. Five subjects, who were knowledgeable about soccer, were shown these "spatially occluded" sequences and the placement of the non-kicking foot was the only cue that was both reliable and was identifiable more than 100ms prior to ball contact. A further test of this response cue's reliability was completed on the penalties of the 1996 European Championships that were held in England. Accuracy of shot prediction in this test was in excess of 85 percent.

The next phase of the study was designed to test the utility of the response cue. Can knowledgeable soccer players and coaches use this information to predict shot direction? Experienced goalkeepers were not used at this stage because of their previous experience and learned habits in the penalty kick situations. We reasoned that it would be difficult for goalkeepers to abandon the cues they had previously used to predict shot direction. We planned to use goalkeepers in a training study which was intended to follow experiment one, where the subjects would participate in enough sessions that our proven prediction strategy would replace any less reliable strategies that the goalkeepers currently used to predict shot direction.

If the response cue can be used effectively by people who are knowledgeable about soccer but are not experienced goalkeepers then it would be worthwhile to develop a training program based upon the use of the response cue. Experiment I used a simulated penalty kick situation in which reaction time, movement time and response accuracy (correctly predicted direction) were measured before and after subjects were given information on the benefit of using the response cue.

METHODS

Subjects

Eighteen experienced soccer coaches volunteered to participate in this study. The 18 coaches were randomly assigned to either an experimental or a control group. All of the subjects gave written, informed consent prior to participating in the study. The reason for using experienced coaches as a subject group was to test a homogenous group of subjects with a very thorough and consistent knowledge of the game of soccer. In addition, it was important that the subjects in this experiment did not already have a determined predictive strategy as many experienced goalkeepers would. This was not designed as a training study but rather an investigation into the effects of recently received, valid response information on an individual's ability to anticipate shot direction. All of the subjects were males between the ages of 25 and 45 (avg. 31.3) and all had been coaching soccer for a period of 5 to 12 years (avg. 8.3). This experiment conformed with the ethical standards for human subjects at the University of British Columbia.

Apparatus and Task

The task was constructed to assess the subjects' ability to predict to which area of the net the ball was directed during a penalty kick. Eight experienced, university (national level) soccer players were filmed taking a penalty kick from the perspective of a goalkeeper. A videotape of these penalty kicks was then compiled to create a visual test of the subjects' predictive abilities.

A total of 100 shots were shown to each subject twice. 46 of these shots were directed toward the right, 44 to the left and 10 were directed towards the center third of the net. Each sequence began with the player initiating their approach to the ball and each sequence was occluded at contact. At the end of each sequence a blue screen appeared for 5 seconds and this gave the subjects the opportunity to complete their task, which was to predict if the ball was directed towards the right, left or center third of the net.

A 3M MP8020 overhead data projector was used to present the videotape representation of the penalty kick. The projector was set at a distance of 15 feet from the screen which created a 4ft. x 6ft. image size. The subjects stood at a control panel with four telegraph keys (a home key and three response keys) at a distance of 15ft. from the screen.

As each penalty taker appeared on the screen, the subjects were instructed to press down on the home key. Each sequence ended (was occluded) at the point of ball contact and this caused the image to disappear and the plain blue image replaced it. The subjects lifted their finger off the home key and moved as quickly and accurately as possible to either the right, left, or center response keys which were positioned an equivalent distance (10cm) from the home key. Response accuracy, reaction time, and movement time were recorded on a Zenith MS.DOS computer, Intel 386 (25mghz). The telegraph keys were connected to the parallel port of the computer and a custom circuit was designed to detect an audio tone on the videotape which was synchronized with the occlusion (contact) point in each sequence. Reaction time measured the time from film occlusion until the subject removed their finger from the home key and movement time was a measure of how long it took the subject to move from the home key to one of the response keys.

A control condition (or phase) was included for both groups at the end of the experiment. The reaction time and movement time for a three choice decision-making task were measured on the same equipment. Subjects were presented with a blank blue screen while they depressed the home key. When the screen appeared blue the variable fore period (1-3 secs) began. A large (2 foot high) white letter (L, R or C) was the imperative stimulus for the subjects to move to the key spatially represented by the letter. That is, when an "L" appeared on the screen, subjects had to move to the left telegraph key (R-right key, C-center key). Subjects completed 15 trials (5 from each condition presented randomly) in this condition (phase). Instructions were, once again, to move as fast and accurately as possible upon seeing the stimulus.

Procedures

In the pre-test phase of the study both the control and experimental group viewed the same 100 penalty kicks and responded to the occlusion frame on the video by predicting the direction of the kick in a reaction time paradigm. During the intervention period both groups were shown 10 full vision (no occlusion) penalty kicks in which the path of the ball after contact was visible.

The control group were then asked if they recognized anything in the video display that would aid their performance in the post-test. They were not given any other information about the task. On the other hand, the experimental group was given information related to the response cue "placement of the non-kicking foot". They were told the foot invariably pointed in the direction which the ball would travel. The ten penalty kicks given in this intervention period were used to illustrate the reliability of this response cue.

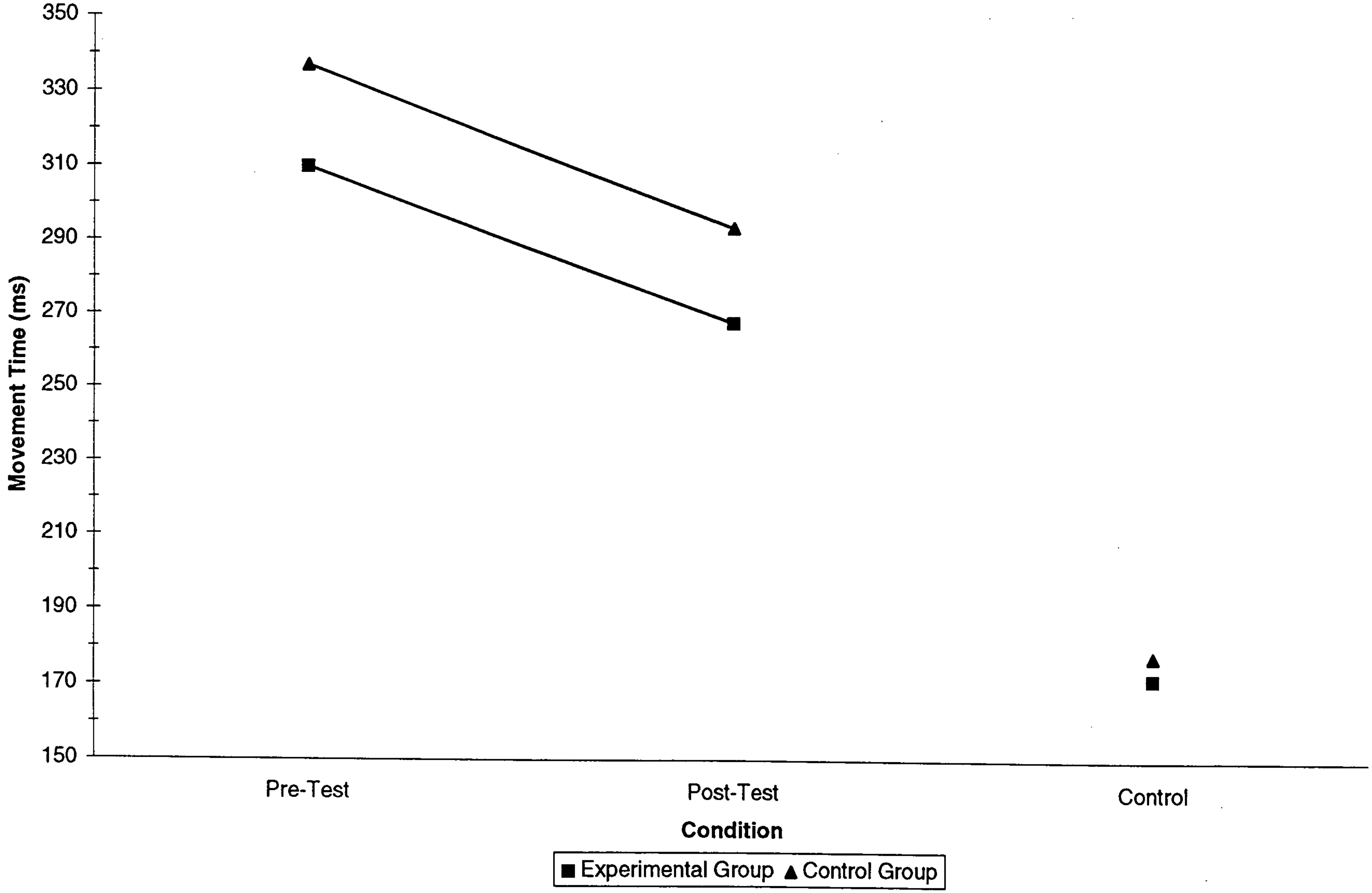
After a 5 minute break, the subjects returned to the testing apparatus to complete the post-test. This consisted of the same 100 penalty kicks that were used in the pre-test. Because of the large number of trials, and the fact that performance feedback was not given, it was felt that there would be no memory effect from the first 100 trials. After the post-test, all subjects completed 15 trials of the control condition (phase).

RESULTS

Three separate group (2) by condition (3) univariate analysis of variance with repeated measure on the second factor were performed to determine the effects of the intervention on the experimental group's reaction time, movement time, and response accuracy. There was no significant main effects or interaction effects for the dependent measure movement time in the pre-test and post-test conditions (phases). However, as can be seen from figure 1, the movement time of subjects in the control condition (phase) was significantly faster than it was during the last fifteen trials of the post-test [$F(1,17) = 29.81$, $p<.05$]. This effect was attributed to subjects using movement time in the penalty kick conditions (phases) to continue the decision making or prediction process involved in the task.

Insert Figure 1

Movement Time
Figure 1



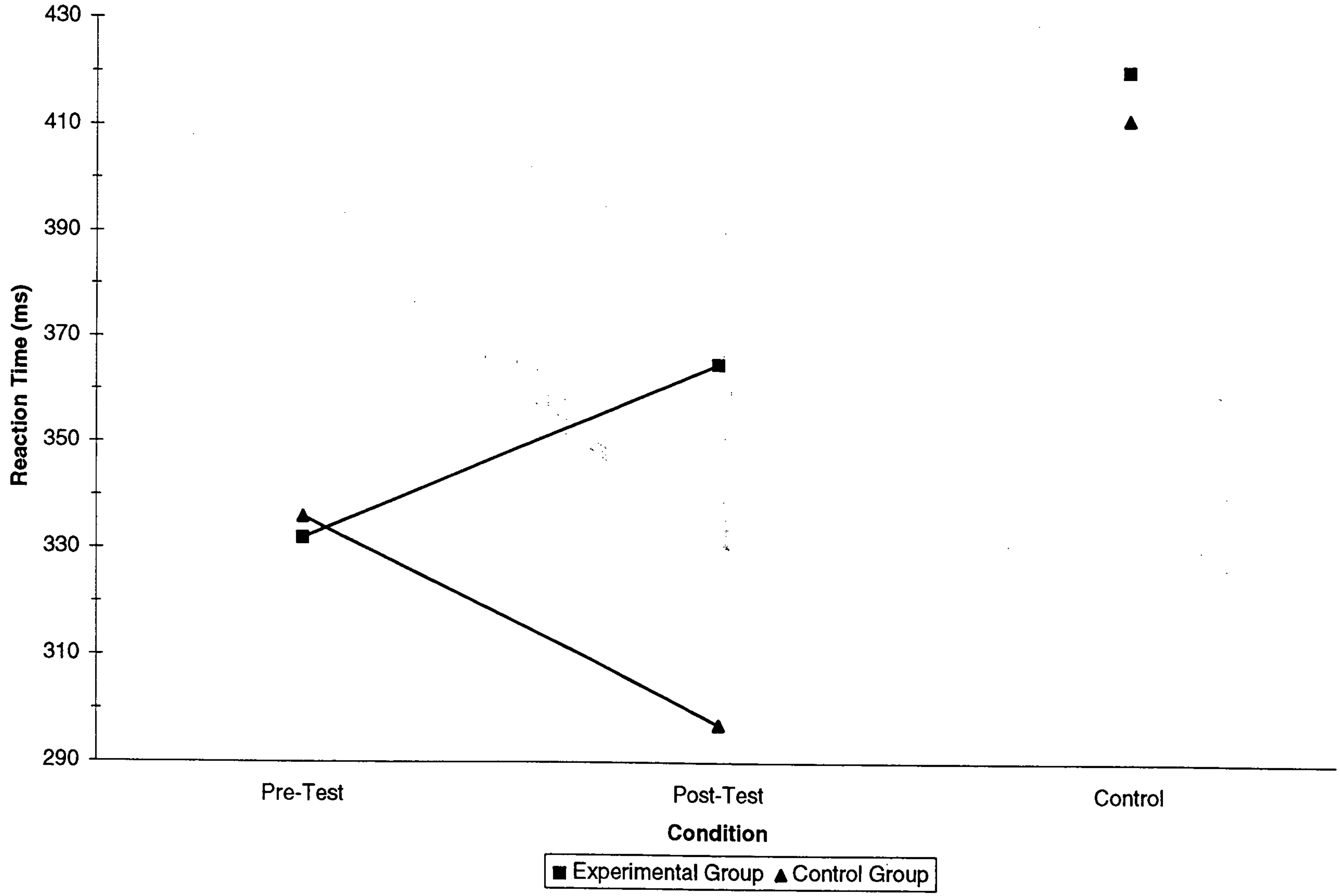
The reaction time data is illustrated in figure 2. The interaction between pre/post condition and group was significant [$F(1,16) = 8.191$, $p<.05$]. The experimental groups' mean reaction time increased from 330 to 370ms while the control groups' reaction time decreased from 340 to 300ms. In addition, subjects in the control condition (phase) were significantly slower to react than in the last fifteen trials of the post-test [$F(1,17) = 43.778$, $p<.05$]. This slowing effect was attributed to the anticipatory nature of the task in the penalty kick conditions (or phases). Subjects sometimes lifted their hands from the home key prior to the occlusion point in the penalty kick trials. However, these subjects were forced to wait for the stimulus to respond in the control phase. This stimulus in the control phase appeared on the screen after the occlusion point on the videotape.

Insert Figure 2

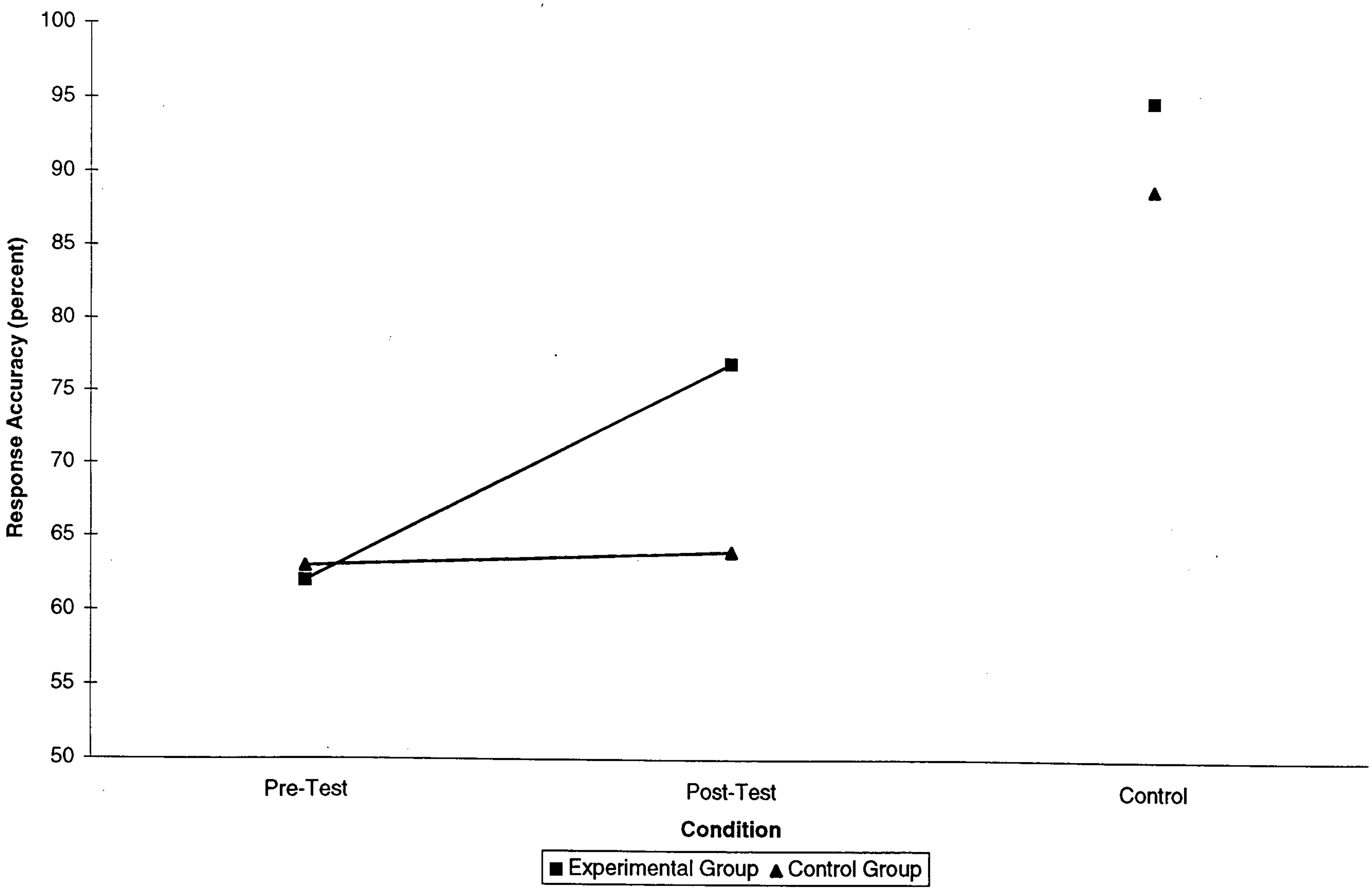
There were significant main and interaction effects for the measure of response accuracy [$F(1,17) = 8.024$, $p<.05$ and $F(1,17) = 6.424$, $p<.05$ respectively]. As expected, the experimental group that received valid response cue information performed better on the task during the post-test trials (see figure 3). It is worth noting that the experimental group predicted shot direction accurately on 77 percent of the trials.

Insert Figure 3

Reaction Time
Figure 2



Response Accuracy
Figure 3



DISCUSSION

It is clear from the results of this study that when knowledgeable soccer coaches are provided with a reliable response cue at a penalty kick situation they significantly improve their ability to accurately predict the direction of the shot. Whereas the control group's performance did not vary over both pre and post-test, the experimental group improved their prediction to a 77 percent level of accuracy.

When both groups were asked if they had used any predictive strategies in the pre-test trials, all stated that they had used one or more response cues. The response cues we identified earlier were all used either in combination or separately. These cues were the starting position of the penalty taker, the path of their approach to the ball, the backward or forward lean of their trunk, the placement of the non-kicking foot, the inward or outward rotation of the kicking leg knee, and the point of contact with the ball. Furthermore, most subjects varied the use of any one cue throughout the study. No subject reported to have used the "placement of the non-kicking foot" as a sole response cue consistently. After the intervention period it is evident that the control group maintained their previous strategies, while the experimental group adjusted to the information that was provided. Self-reports from the control group of coaches confirmed that they maintained their strategies throughout the experiment.

Supporting evidence can also be seen in the reaction time data. After the intervention, reaction time decreased for the control group but increased for the experimental group. Given the nature of the task, subjects would be expected to decrease their reaction time over 200 trials (100 pre-test and 100 post-test) if they approached each trial with a similar strategy, as was the case with the control group (reduction of reaction time from 335 to 296 ms). Subjects became more familiar with the response characteristics of the task and also familiar with using the anticipatory cues provided by the events leading to the penalty kick. If no cues were available the subjects would be reacting between 60 to 100ms later as can be seen from a comparison with the control condition or phase (laboratory choice reaction time task: 3 choices, variable fore period and equiprobable stimuli). However, providing experimental subjects with a valid response cue that occurred late (close to the imperative signal) had the effect of slowing their reaction time (365ms), although not to control condition values. It appeared that subjects in the experimental group were involved in extra cognitive processing as a consequence of searching for, and processing, the late occurring, relevant response cue.

Although the results of the study are encouraging with respect to the utility and accuracy of the response cue "placement of the non-kicking foot", it is clear that before it can be used effectively by goalkeepers a training program has to be developed. The program was designed to reduce the time goalkeepers spend in identifying the response cue and then responding as quickly as possible. Reaction times in the order of 300ms or higher will not be fast enough for the goalkeeper to stop the penalty shot and must therefore be brought down to levels between 100 and 200ms.

EXPERIMENT II - INTRODUCTION

This study was designed as a visual training program which would improve the abilities of a group of soccer goalkeepers to anticipate the direction of a penalty kick through the utilization of reliable, pre-contact response cues. It was proposed that observations of valid response information during video simulations of penalty kicks would enhance the visual skills or expertise of goalkeepers and transfer to improved shot stopping in the penalty kick situation. Support for a program of this nature must show that expertise has been hastened in other sports through the use of visual observations. There has not been a great deal of research conducted in this area but what research has been performed is supportive of the ability of visual displays to enhance the perceptual expertise of sport performers. Studies conducted in ice hockey (Thiffault, 1974) and baseball (Burroughs, 1984) have shown that visual training can improve the accuracy of decisions made in simulated performance situations.

In a very early study conducted in this area, Thiffault (1974) trained ice hockey players to make faster tactical decisions following brief exposures to slides of game situations. Many of these early studies used slides to improve visual skills. This methodological limitation was corrected in later studies which used dynamic video tape that resulted in a more valid simulation of the visual display. Despite the use of static visual displays, results of this study demonstrated that subjects' decision making reaction time was reduced following the visual training. Thiffault designed a transfer task for this study using cones on an actual ice surface, where he reported that subjects' exhibited an enhanced decision making ability. Subjects were placed on the ice surface in a position where it was assumed they had possession of the puck. They were then shown brief views of player formations and had to decide whether to pass, shoot or skate with the puck. The lack of ecological validity in this transfer task has to be seen as another limitation of this research. The study failed to show that the visual training which occurred would facilitate performance in a real game situation. In any transfer, training study, the most vital and yet most difficult objective to achieve is to assess whether improvements seen in training would transfer to improvement in actual game performance.

In a visual training study designed for baseball, Burroughs (1984) developed video simulations of pitchers throwing fastballs and curves. A group of collegiate batters participated in this study (n=59) designed to evaluate batters' improvements in pitch recognition and location prediction following repeated observations of the video display. Results indicated that significant gains in location prediction and pitch recognition occurred for all subjects. These results clearly demonstrate that the visual simulation training improved the batters' perceptual abilities. A similar limitation of this research, however, was that Burroughs made no attempt to transfer these enhanced visual skills back to actual game conditions.

Another study which supports the use of video observations to enhance the visual expertise of athletes was conducted by Christina, Barresi, and Shaffner (1990). These researchers studied a collegiate football linebacker to determine if accuracy of response selection could be improved by viewing video simulations from a perspective valid to his position. The study's task required the linebacker to view cues in the back field and tight end positions and make the most appropriate response to these cues as quickly and accurately as possible. Data revealed that there was an improvement in response selection accuracy. Training with valid film displays can be an effective method for improving the perceptual skills of athletes. An important aspect of this study is that the researchers highlighted the critical areas of the visual display. Christina, Baressi, and Shaffner (with the help of an expert coaching staff) determined in advance what the most valid or reliable response cues were. The linebacker subject was not just shown film but was given specific feedback to guide his visual training.

A final study which provides further support for the use of video simulations to enhance an athlete's perceptual skills was conducted by McMorris and Hauxwell (personal communication) These researchers investigated the value of using video observations to enhance the anticipatory abilities of soccer goalkeepers. Thirty male college players were given a pre-test of anticipatory ability where they viewed penalty kicks occluded at different points in the film display. The subjects were then randomly separated into two experimental and one control group. The two experimental groups viewed 250 and 500 full vision penalty kicks, were instructed to look for certain pre-contact cues, and then all three groups were retested on their anticipation skill. Results supported the present investigation by indicating that the two experimental groups improved their anticipation while the control group did not.

There are some limitations within this study which cause the validity of the results to be questioned. Outfield soccer players were used as a subject base for the study instead of goalkeepers. While this subject population is appropriate for introductory research, a group of goalkeeper subjects would improve the studies validity. Furthermore, the training film used in the study altered the visual display from the two assessment conditions and subjects did not have to attend to pre-contact information because the film was not occluded at impact. More importantly, the pre-contact cues were not used in a systematic manner. The researchers did not discuss how they determined the reliability of the response information or in what order of importance the cues were provided to the subjects.

Experiment II was designed to use a specific training technique that was intended to improve a goalkeeper's ability to anticipate more accurately the direction of the penalty kick. This program intended to teach goalkeepers to recognize the reliable response cue, "the placement of the non-kicking foot", and it was proposed this would result in an improvement in the subject's ability to accurately predict shot direction. Subjects practiced their ability to anticipate ball direction in a laboratory by responding to an ecologically valid film display of penalty takers, taken from the perspective of the goalkeeper. They also had the opportunity to practice their predictions during a transfer task in a gymnasium, which used actual shots from outfield players.

A unique feature of this study is that we used an eye movement recorder to generate feedback (knowledge of results) in the form of gaze control data which was intended to improve the goalkeepers' ability to visually focus on the non-kicking foot throughout the pre-contact sequence. The goalkeepers used the eye track recorder for 40 trials in the laboratory and 40 trials in the transfer task. Therefore, subjects received this form of feedback eight times (one feedback session for every five trials) both in the laboratory and the gymnasium (transfer task) settings. While the eye track recorder has been used to investigate expert athletes visual search and gaze control, (Vickers, 1985), the use of this device as a training technique to improve athletes' ability to focus on the most pertinent information in their visual display was one of the most innovative aspects of this study.

Subjects received visual feedback from the eye track recorder following a set of 5 trials. A video recording was created for every trial of eye track data. The recording displayed the cursor from the eye track recorder (indicating exactly what the subjects' were looking at) superimposed over top of the subject's complete visual display. Therefore, the goalkeepers were provided with a knowledge of results of the exact position of the non-kicking foot of the penalty taker and precisely what they were looking at, through the entire pre-contact sequence. Researchers highlighted the difference or distance between the non-kicking foot and the eye track cursor and encouraged subjects to continually reduce this distance throughout the shot taker's approach to the ball. It was proposed that this specific knowledge of results following sets of 5 trials would teach goalkeepers to accurately fixate on the non-kicking foot from the player's movement initiation right up until the point of ball contact.

Another unique aspect of this research was the use of a transfer task and both a pre and post-training assessments of the goalkeepers' shot stopping ability in the actual penalty kick situation. A critical limitation of all of the visual training studies reported previously was the ability of the researchers to show that any enhanced perceptual ability would actually transfer to improved performance in real game situations. One of the benefits of investigating the penalty kick in soccer is that it represents a discrete event which can be separated from the rest of the soccer game. Therefore, an assessment situation was created which exactly replicated the task faced by goalkeepers in actual game conditions.

Another important aspect of this research is that the goalkeepers received no physical training throughout the program to improve either the speed or the technical skill with which they moved to intercept the path of the ball. If this type of training were part of the program it would be difficult to determine what actually improved their performance. It was the intent of this research to discover if the visual skills acquired in the laboratory alone would improve performance in stopping actual penalty kicks.

There is some theoretical support for a training program of this nature to be able to transfer to improved performance in game conditions. Bransford, Franks, Morris and Stein (1979) proposed a theoretical view of transfer of learning termed transfer-appropriate-processing (see Chamberlin and Coelho, 1993). Bransford and his colleagues reported that transfer can occur between two tasks if their is a high degree of similarity between the cognitive processes required by the two tasks. In support of our research, Chamberlin and Coelho state, "...a perceptual training device would need to invoke the same cognitive processing scheme as would occur in an actual game situation." The training device created for this experiment does require the same cognitive processes required by goalkeepers in the penalty kick. Subjects are required to attend to information in a visual display and based on this information, they are then required to predict the direction of the ball by creating a physical response (moving hand to direction key). In view of this support, it was proposed that the visual training involved in our program would transfer to improved performance in the actual penalty kick situation.

METHODS

Subjects

Eight male goalkeepers volunteered to participate in this experiment. The study was designed for an elite group of British Columbia's goalkeepers. Approval of the program was granted by both the provincial (BCSA) and the national (CSA) sport governing bodies. The subjects ranged in age from 18 to 27 years of age (avg. 22.8). Four of the subjects had national level experience (played at the university level) and four had international experience from playing for one of Canada's national teams. All of the subjects who participated in the study gave written, informed consent. The experiment conformed to ethical standards for human subjects at the University of British Columbia.

Apparatus and Task

Experiment II comprised 8 different training phases. Each goalkeeper participated in all 8 phases of the program over an 8 week period. All phases of the study took place at the University of British Columbia. Phase 1 and 8(pre and post-test of shot stopping ability) took place on the varsity soccer fields. Phases 2 to 6 were completed in the motor control laboratory at the War Memorial Gymnasium and phase 7 (the transfer task) was completed at the Osborne Center Gymnasium.

Both pre and post (phase one and eight) assessments of shot stopping ability were given to each of the goalkeepers. Four out of a group of six outfield players took ten shots each at each of the goalkeepers. The assessments took place inside the "18 yard box" penalty area of a soccer field at the University of British Columbia. This situation replicated the exact position of goalkeepers and shot takers in game conditions. Each trial was recorded on videotape. Cameras were positioned behind the goal net, behind the shot taker, and at the side of the soccer field. These camera positions gave the researchers three different views in which to analyze phases one and eight of the program. Data was collected on response accuracy (the number of correct predictions) and the number of shots stopped (save percentage). The additional cameras allowed the researchers to record the movement times of each goalkeeper, which was defined as the amount of time from movement initiation until any part of the body crossed the path of the ball flight. It was critical that each of the goalkeepers reduce their movement time to intercept the path of the ball to 500ms or less. This figure was based on our initial research which demonstrated that the average time of ball flight in our World Cup penalty kicks was slightly less than 500ms. Each subject was also questioned on the predictive strategies they used to try and stop penalty kicks and the amount of success they had both predicting shot direction and actually stopping penalty kicks. All of this data gave the researchers a detailed profile on each goalkeeper prior to their participation in the program.

Phase two to six of the training program used a valid film simulation of the perceptual display in the penalty kick situation which was constructed to assess each subject's perceptual ability. Film was constructed from the perspective of the goalkeeper using a Super VHS video recorder. Five national and five international level outfield players were filmed taking ten penalty kicks each. The location of each shot was recorded and then as in experiment one, each shot was occluded at the point of impact with the ball. A total of

100 shots were created for the film display. At the end of each sequence a blue screen appeared for 5 seconds and this gave the subjects the opportunity to complete their task, which was to predict if the ball was directed towards the right, left or center third of the net. This 5 second interval also allowed the researchers to give feedback to the subjects on the accuracy of their response, as well as their reaction time and movement time taken to complete the task. Feedback was given to the subjects after each trial during all the laboratory phases of the program except when the subjects were wearing the eye track helmet.

A 3M MP8020 overhead data projector was used to present the videotape representation of the penalty kick. The projector was set at a distance of 15 feet from the screen which created a 4ft. x 6ft. image size. The subjects stood at a control panel with four telegraph keys (a home key and three response keys) at a distance of 15 feet from the screen.

As each penalty taker appeared on the screen, the subjects were instructed to press down on the home key. Each sequence ended (was occluded) at the point of ball contact and this caused the image to disappear and a plain blue image replaced it. The subjects lifted their finger off the home key and moved as quickly and accurately as possible to either the right, left, or center response keys which were positioned an equivalent distance (10cm) from the home key. Response accuracy, reaction time, and movement time were recorded on a Zenith MS. DOS computer, Intel 386 (25mghz). The telegraph keys were connected to the parallel port of the computer and a custom circuit was designed to detect an audio tone on the videotape which was synchronized with the occlusion (contact) point in each sequence. Reaction time measured the time from film occlusion until the subject removed their finger from the home key and movement time was a measure of how long it took the subject to move from the home key to one of the response keys. Due to the anticipatory nature of the task, some reaction times were less than zero. Subjects sometimes lifted their hand off of the home key prior to ball contact or the occlusion point on the videotape.

Phase four and seven of the training program included the use of the ASL SU 4000 eye track system to analyze the eye fixations of each of the goalkeepers during each trial. The ASL SU 4000 is a monocular reflection system that measures eye line of gaze with respect to a helmet that the subject wears. A cursor is superimposed on the video display to show precise point of gaze or fixation. The system has an accuracy of +/- 1 degree visual angle with a precision of 1 degree. The system was used as feedback or knowledge of results for each subject to indicate exactly what they were looking at throughout the pre-contact sequence of events.

During phase four and seven of the program, the subjects used the helmet while viewing 40 film representations of the penalty kick. After sets of 5 shots, feedback was given to the subject in order to train their ability to fixate on the response cue, "the placement of the non-kicking foot". At the end of 5 trials the main VCR which was being run through the overhead data projector was stopped and a second VCR which was recording both the trial and the cursor which displayed the gaze fixations from the eye track system was rewound and then played through the overhead data projector so the image appeared on the same screen 15 feet away from the subject.

During the seventh phase of the program, each subject progressed to using the eye track system in a gymnasium setting. Each goalkeeper faced four elite outfield players taking penalty kicks while wearing the eye track system. Again, feedback was generated onto monitors beside the goal net which displayed exactly what pre-contact information each goalkeeper was fixating on. The goalkeepers faced 40 penalty kicks wearing the eye track helmet which were again completed in sets of 5 trials. A VCR was connected to the eye track system which recorded each penalty kick superimposed with the eye track cursor so the goalkeepers could again see exactly what they were looking at. After a set of 5 shots, the VCR was stopped and the tape which showed the penalty and the eye track data was rewound. The subjects moved out of the goal area and were brought to a 25cm monitor which was positioned beside the goal net. Researchers viewed each of the trials with the goalkeepers and again highlighted both the non-kicking foot path and the path of the eye track cursor which showed the subjects exactly what they were looking at. After viewing all 5 trials on the monitor, the goalkeepers returned to the goal to face subsequent shots.

Procedures

Eight goalkeepers were involved in a training program designed to improve their ability to visually attend to the precise response cue that would allow them to accurately predict the direction of a penalty kick. The dependent measures throughout the laboratory portion of the program were the goalkeepers' response accuracy, reaction time, and movement time. The dependent measures in the pre and post assessment were response accuracy, save percentage, and the goalkeepers' movement time taken to move horizontally and cross the path of the ball. The dependent measure in the transfer task was response accuracy. Radial error was used as a dependent measure for the eye track data. Radial error was a measure of the distance of the eye track cursor from the position of the non-kicking foot in the shot takers' approach to the ball. This radial error eye track data was measured both in the laboratory and during the transfer task.

Phase 1

Each goalkeeper took part in an identical training program. The initial objective of the program was to determine how each goalkeeper performed in the penalty kick situation. First, the subjects were asked to explain their usual predictive strategy. Each goalkeeper was asked, "When faced with a penalty kick do you move early, wait for ball impact or wait for ball flight information?" They were also asked, "What cues do you use to anticipate the direction of a kick and how successful do you believe this predictive strategy is?"

In this initial phase of the program subjects also received a pre-training assessment of their shot stopping ability. This assessment took place on one of the soccer fields at the University of British Columbia. After a 15 minute warm up period, each goalkeeper faced 40 penalty kicks taken by expert (national level) outfield players. The researchers attempted to replicate the exact conditions of a penalty kick in an actual soccer game. The assessment took place after the goalkeeper had warmed up and stretched, and the three cameras were in position. Although no specific time frame was set, each goalkeeper had as much time as they needed to prepare for the next shot. It was imperative that performance of the goalkeepers would not be affected by the repetition of 40 penalty kicks. Evaluation of their performance was based on response accuracy, save percentage, and the goalkeepers movement time. Analysis of the outfield players' penalty kicks in both the pre and post-training assessments (phase one and eight) revealed that these national level players' shots took approximately 500ms to cross the goal line.

Phase 2

The second phase of the program involved visual training sessions using video taped simulations of the perceptual display in the penalty kick situation. Each subject viewed 100 video simulations of penalty kicks and attempted to predict to which side of the goal the ball was directed (see experiment one for more detail). The response accuracy, reaction time and movement time data was used to give feedback to the subject after each trial.

As each subject came into the laboratory, the researchers reviewed each subject's pre-test assessment of shot stopping ability. Subjects were given feedback on their save percentage, percentage of correct predictions, and average movement time over the 40 penalty kicks. The researchers explained the laboratory set up of equipment and demonstrated the task of responding to the video simulations of penalty kicks using the control panel. Each subject then performed 100 trials of penalty kick simulations (the same tape as in Experiment I) using their own predictive strategy, where no immediate feedback was given. At the end of the session each subject was given feedback on their overall response accuracy during the first 100 trials. The combination of the pre-test feedback and this laboratory feedback gave each goalkeeper an understanding of how inaccurate their current predictive strategy was. This was an important step, because changing these predictive strategies was the main goal of the early portion of the visual training program.

Phase 3

After this initial session using their own strategy, each subject was informed about the potential for accurate prediction by utilizing the shot taker's placement of the non-kicking foot as the single, most reliable response cue. The same full vision penalty kicks which were used as part of the intervention in Experiment I were shown to the goalkeepers. The researchers discussed with the goalkeepers the severe time constraints of the penalty kick situation and how attending to a single cue would improve their ability to predict shot direction. The subjects were then informed about the design of the entire program and how they would progress through each phase. The goalkeepers then returned to the control panel and completed 100 more trials from the videotape used in Experiment I. After each trial in this phase, the goalkeepers received feedback on their performance (response accuracy, reaction time, and movement time) and were encouraged to utilize just the one reliable response cue to predict shot direction. At the end of this phase, goalkeepers were given their overall response accuracy for the last 100 trials and the researchers highlighted the differences between their first and second sessions of video simulations. It was predicted that the accuracy of their phase three results would motivate the goalkeepers to continue their participation throughout the program.

Phase 4

The fourth phase of the program added the ASL SU 4000 eye track system to the perceptual training program. The eye track system taught the subjects to fixate on only the most valid response cue by giving them precise feedback as to what their gaze was fixating on after each set of five trials. Each subject participated in one session of 40 trials using the eye track system. A new videotape was also used during this portion of the program. It was considered that there would be memory effects from these trials if we had continued to use the videotape from Experiment I. Therefore, a new tape of 140 video simulations of penalty kicks was created using a Super VHS video recorder. The tape compiled penalty kicks from 14 expert outfield players who had either a national or an international level of playing experience.

Each subject returned to the lab one week later to perform this session of the program. The researchers explained the use of the eye track system and demonstrated how each subject would respond to the video simulations while wearing the eye track helmet. Each subject was then calibrated to the system to ensure that the eye track cursor that was displayed on the video screen was tracking their exact gaze fixations. The subjects then completed 5 trials of video simulations using the control panel to additionally generate response accuracy, reaction time, and movement time data. At the end of the 5 trials, the tape was stopped and another VCR which recorded both the image of the penalty taker and the eye track cursor position throughout the sequence, was played back for the subjects. Researchers highlighted the path of the non-kicking foot in these trials and the exact position of the eye track cursor throughout the sequence. Subjects were encouraged to focus on the non-kicking foot of the penalty taker throughout their approach to the ball. Each subject performed 40 trials and feedback on the eye track data, response accuracy, movement time and reaction time was given. Each goalkeeper, therefore received 8 sessions of feedback wearing the eye track helmet during phase four of the program.

Eye track recorder knowledge of results was not provided on every trial due to time limitations in delivering this form of precise, technical feedback. Each time eye track feedback was given, the main visual display was shut down and the eye track recording was rewound to the correct point on the tape. The eye track tape was then played back providing the subject with knowledge of results, highlighted by the researcher. This process took several minutes and when researchers attempted the process for every trial, the "test" subject was able to complete only a very limited number of trials. Feedback for the dependent measures of reaction time, movement time and response accuracy was provided after every trial because this information was able to be delivered in less than 5 seconds. There was no time limitation with providing this form of knowledge of results.

Phase 5

Phase 5 of the training program took place on the same day as phase 4. Once the goalkeepers took off the eye track helmet and were given a 5 minute break, they returned to complete 45 more video simulations of penalty kicks using the new Super VHS videotape. Feedback on their reaction time, movement time, and response accuracy was now given after each trial.

Phase 6

Subjects returned to the laboratory one week later to participate in the sixth phase of the visual training program. Each goalkeeper viewed and responded to 140 trials of penalty kick video simulations. Again, as in phase 5, feedback on their response accuracy, reaction time, and movement time was given after each trial. At this point in the program, subjects were encouraged to continue to reduce their reaction and movement times while maintaining an acceptable level of response accuracy.

Phase 7

The seventh phase of the program allowed the goalkeepers to transfer their enhanced visual skills into a more ecologically valid setting in a gymnasium (using the exact dimensions of a field setting penalty kick). This progression was critical if their enhanced perceptual skill was to result in improved shot stopping in the actual penalty kick situation. Each goalkeeper returned one week after the final laboratory sessions and participated in one transfer session where they faced 40 shots from the same group of expert outfield players who participated in the pre and post-test assessments (phases one and eight). During the transfer phase of the program, subjects were asked to respond to the direction of the kick by extending their arm straight out in the direction they predicted the shot would travel.

As each subject entered the gymnasium, they were again calibrated to the eye track system and the transfer task was explained to them. After each trial, researchers highlighted the accuracy of their response. After each successive 5 trials, subjects left the goal area and walked over to where the eye track system monitors were positioned beside the goal net. The VCR which was recording both the trial of the penalty kick and the eye track cursor data was rewound and played back for each subject. Researchers again highlighted the path of the penalty taker's non-kicking foot and the exact position of the eye track cursor (what the subject's were looking at) throughout the pre-contact sequence. After each feedback session, subjects returned to the goal area to complete another set of five trials. Therefore, each subject received 8 sessions of feedback on the amount of error (distance between the foot path and the eye track cursor) in their eye track data. Any discrepancies between the optimal and the subject's fixations must be corrected during this phase of the program. It was the objective of this phase of the program to ensure that transfer to a more ecologically valid setting did not disrupt the predictive strategy that was learned during the video portion of the training program.

Phase 8

The final phase of the program was the post training assessment of shot stopping ability. Subjects returned one week after the transfer task to complete the training program. Again, subjects were given the opportunity to warm up and stretch, and then the final assessment began. This assessment was conducted in the same area as the pre-test (phase one) and the same three cameras recorded the event for later analysis. Subjects were also given sufficient time between penalties so that fatigue would be minimized as a factor in the assessment. The same three dependent measures as in the pre-test were generated. Response accuracy, save percentage, and movement time data were compared to the data generated in the pre-test (phase one). The effectiveness of the program was evaluated, in part, on the performance of each goalkeeper on each of these three dependent measures (response accuracy, save percentage and movement time). At the end of the post-test, each goalkeeper was interviewed on their perceptions of the program. Subjects were asked about the effectiveness of different phases of the training. Researchers also inquired about each goalkeeper's success and confidence on using and continuing to use, the placement of the non-kicking foot, as a reliable response cue to predict the direction of a penalty kick.

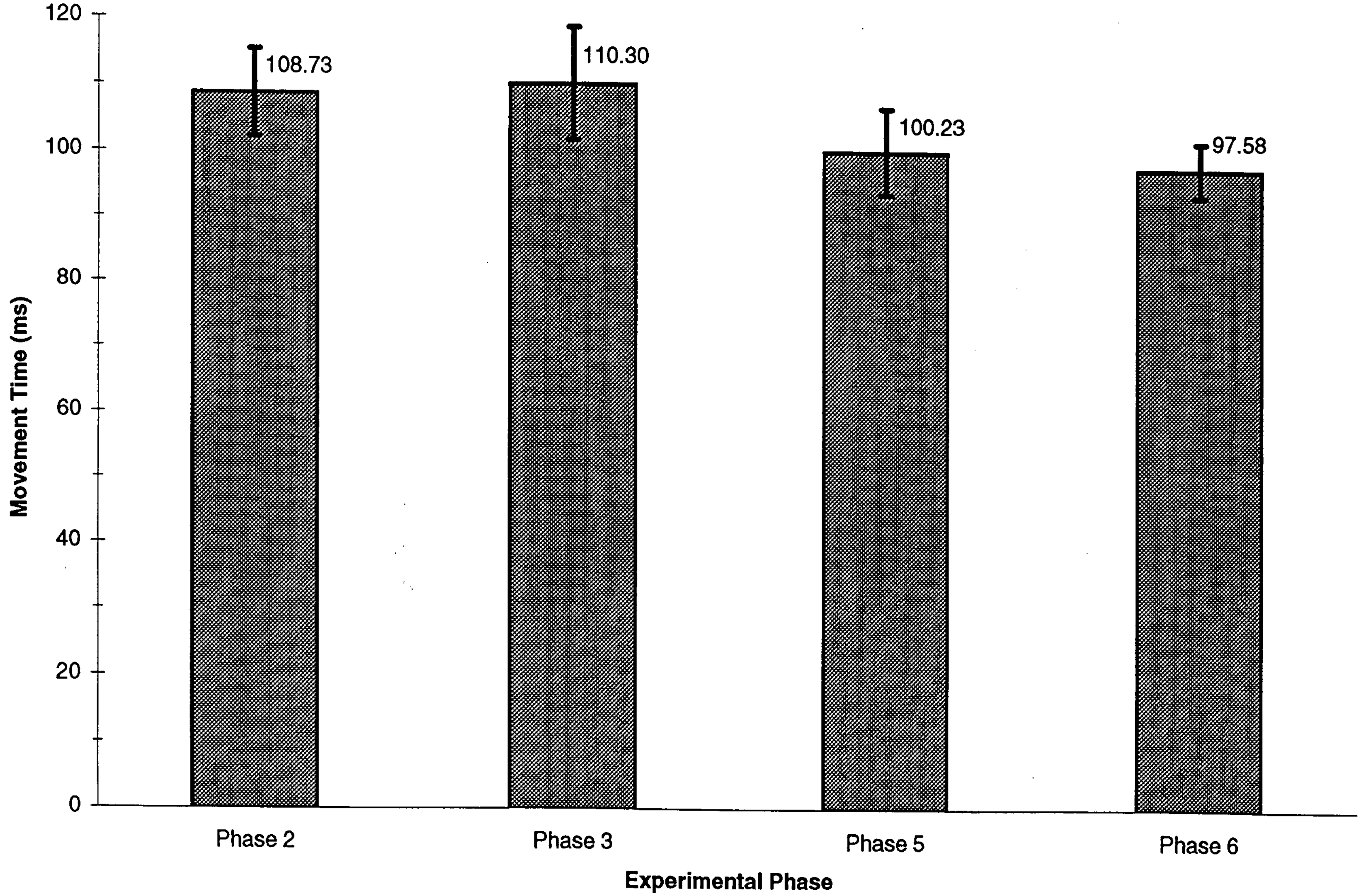
RESULTS

Three separate univariate one way analysis of variance with repeated measure on the phase of the program were used to determine the effects of the laboratory training sessions on the goalkeepers' reaction time, movement time, and response accuracy during the laboratory phases (phases two to six) of the training program. There were no significant main effects for the dependent measure movement time, as can be seen from figure 4 ($p = .08$).

Insert Figure 4

There was, however, a significant main effect for reaction time. [$F(3,21) = 4.7$,$p<.05$]. The data is illustrated in figure 5. Mean reaction time increased from 64.5ms in phase 2 to 169.5ms during phase 6. Reaction times increased significantly in phase 3, after the information about the response cue was provided and then goalkeepers' reaction times

Movement Time
Figure 4



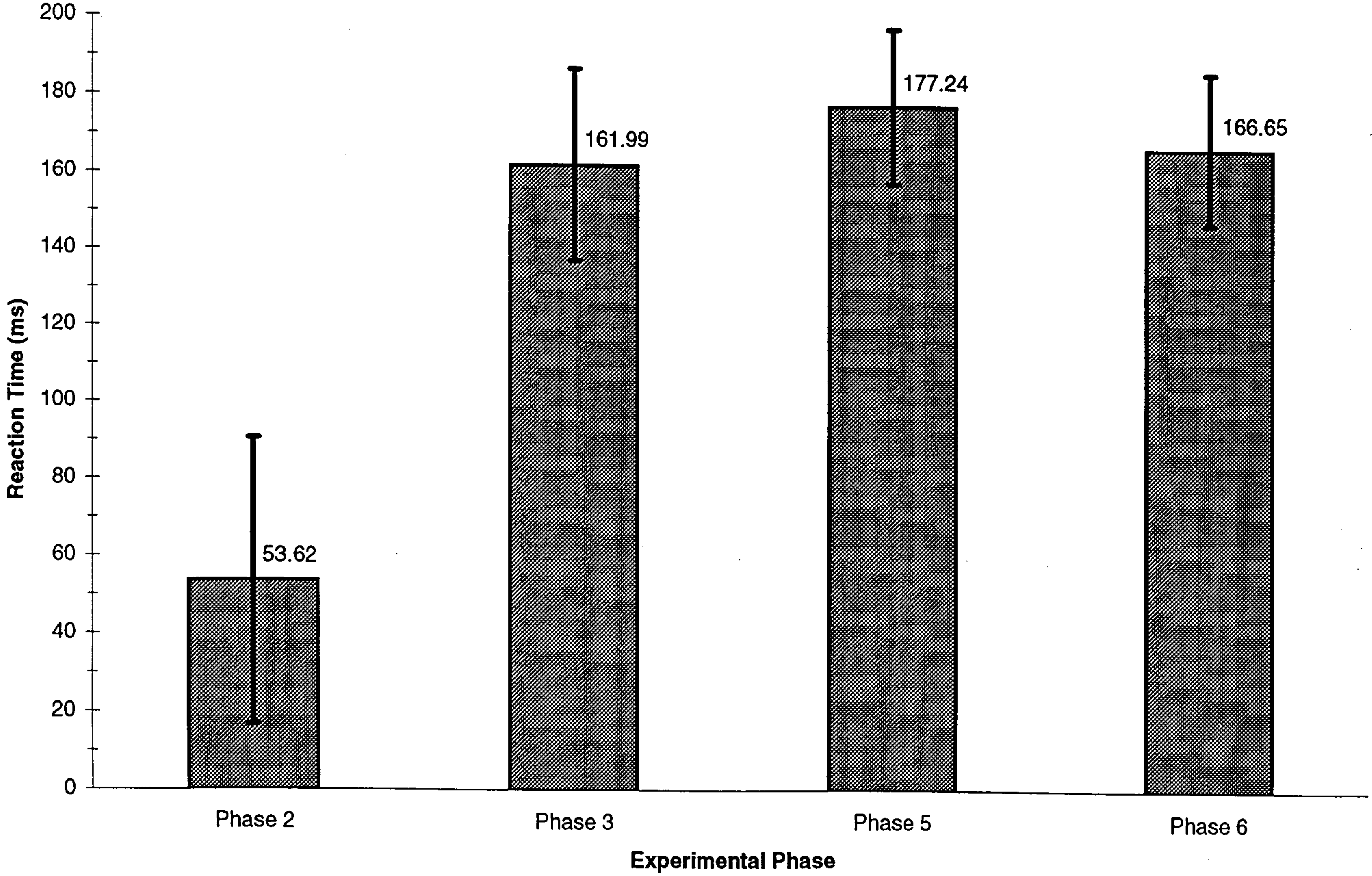
began to decrease throughout the remainder of the laboratory training. A Tukey post-hoc test revealed that the significant change in the reaction time data was between phase 2 in the laboratory and the three other laboratory phases. There was no significant differences in reaction time between phases three, five and six in the laboratory.

Insert Figure 5

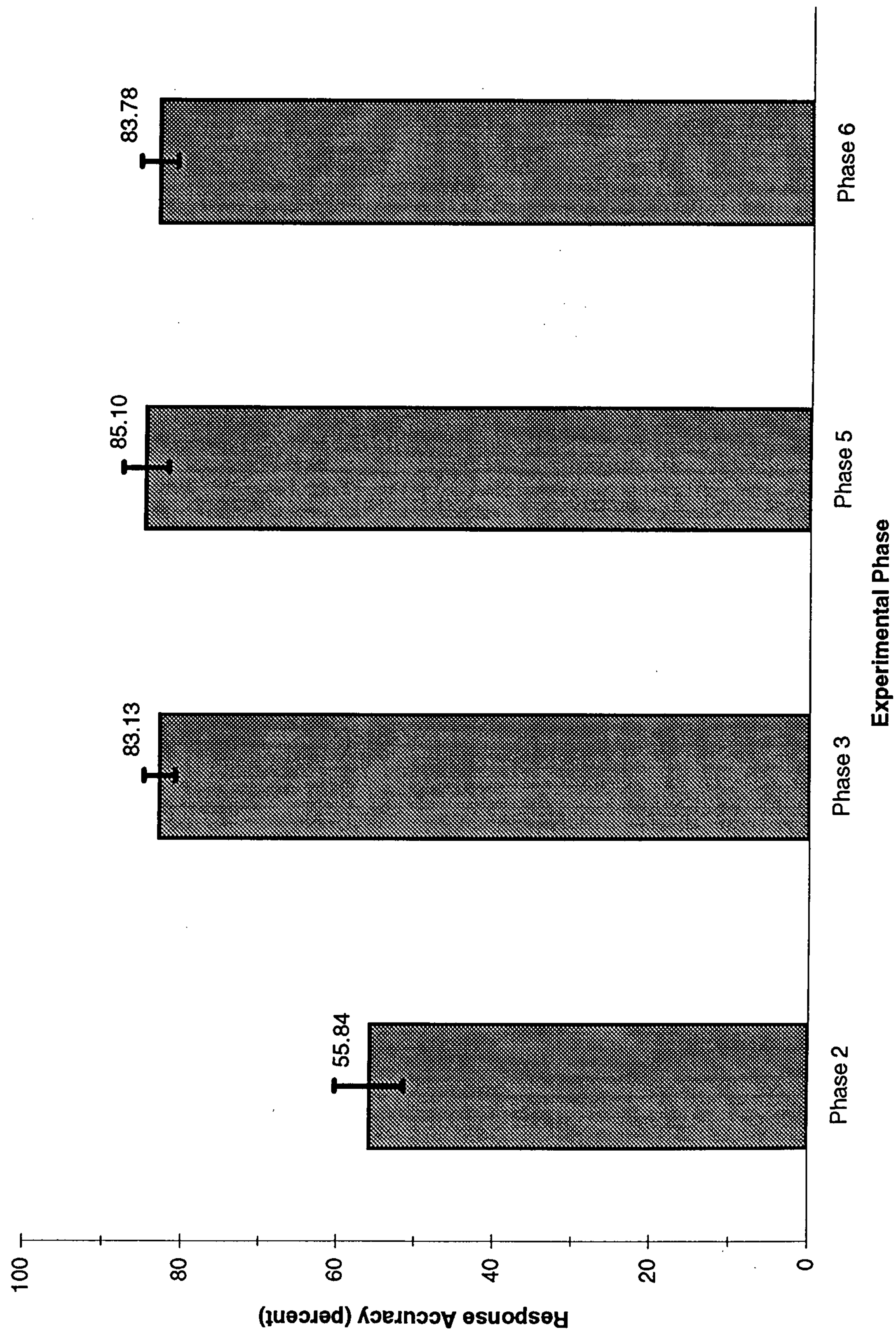
There was a significant main effect of the subjects' response accuracy throughout the laboratory training sessions [$F(3,21) = 22.8$, $p < .05$]. After the goalkeepers received the information regarding the non-kicking foot as a reliable predictor of shot direction (at the end of phase 2), the accuracy of their response predictions significantly increased (see figure 6). Subjects response accuracy increased from 58 percent in phase 2 to 83 percent in phase 6. A Tukey post-hoc test revealed that there was a significant change between phase 2 of the program (where the goalkeepers were employing their own strategy to predict shot direction) and phase 3 of the program (after the goalkeepers had received information about the reliability of the response cue). The post hoc test also revealed that this significant difference was also evident between phase 2 and phases 5 and 6 of the laboratory training. The goalkeepers maintained their high level of prediction accuracy in the later phases of the laboratory training.

Insert Figure 6

Reaction Time
Figure 5



Response Accuracy
Figure 6



A one tailed, paired t-test was used to determine the effects of the training program on the dependent measures of response accuracy, save percentage, and goalkeeper movement time between the pre and post-training assessments of shot stopping ability. The t-test supported the analysis of variance on response accuracy by confirming that there was a significant change for the subject group in response accuracy between the pre and post-tests. The goalkeepers response accuracy increased from 47 percent in the pre-test to 72 percent in the post-test.

A further one tailed, paired t-test also revealed, however, that there was no significant change between the goalkeepers movement time ($p = .09$) and save percentage ($p = .34$) from the pre to the post-training assessments.

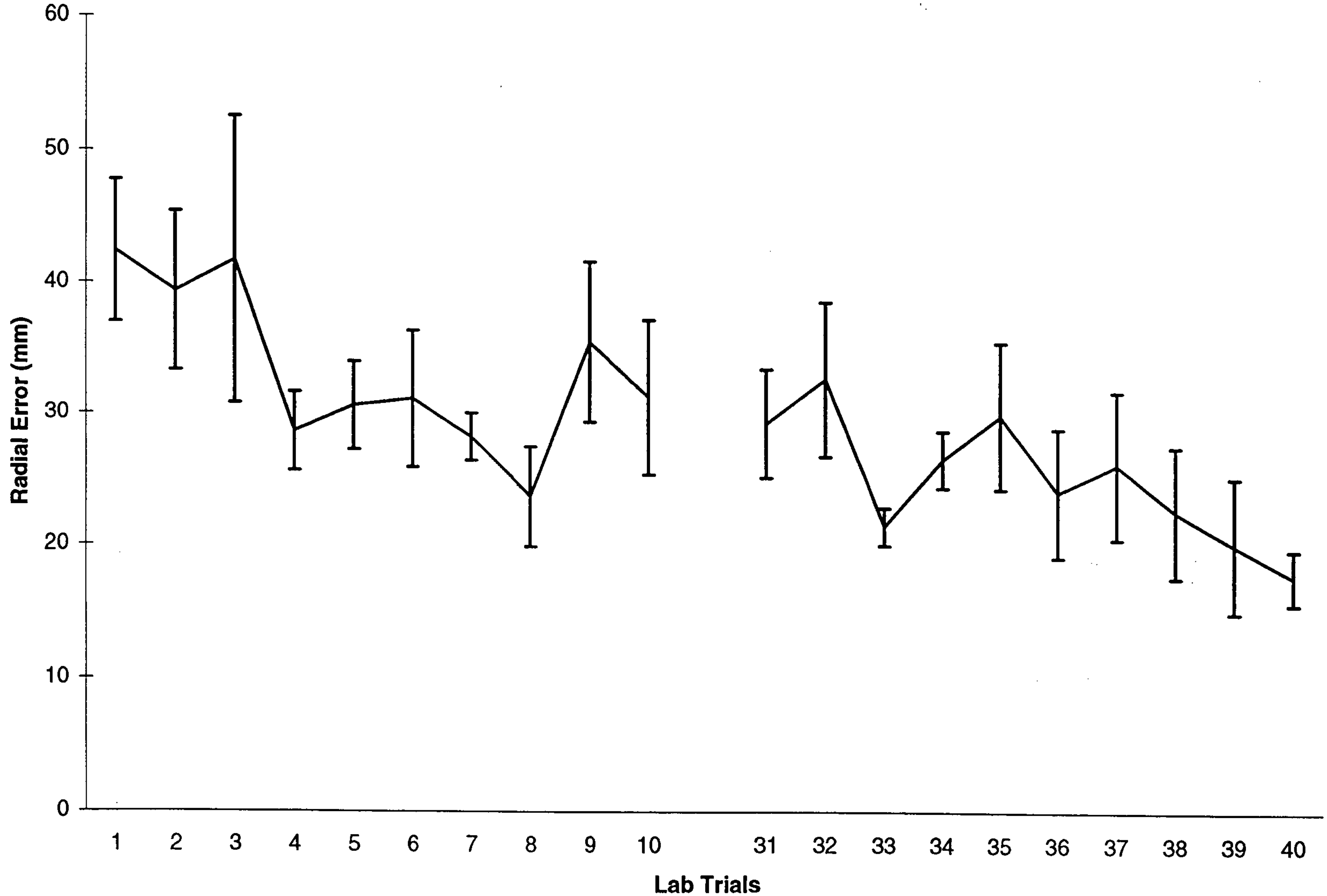
Radial error was the dependent measure used to analyze each goalkeeper's eye track data. Each trial that the subjects completed with the eye track system was compiled on a videotape. Each trial showed both the penalty taker, the path of their non-kicking foot, and the position of the eye track cursor. These videotaped trials were then played through the MP 8020 overhead data projector and displayed onto the wall of the laboratory which had a blank graph positioned on it. The final position of the shot taker and the positions of the non-kicking foot and the eye track cursor were plotted backwards from the point of ball contact, one second (30 frames) into the pre-contact sequence. It is important to note that this one second brought the film to the point where the penalty taker was initiating their approach to the ball.

This plotted data was then transferred onto an customized Excel spreadsheet and a second plot of the raw coordinates was created by the program. Radial error was determined by measuring the distance of the eye track cursor from the position of the non-kicking foot for all 30 frames of each trial. Radial error means were then calculated for trials 1 to 10 and 31 to 40 in the laboratory and trials 1 to 40 in the transfer task. These radial error means were then plotted for the entire group across both the laboratory and the transfer task sessions.

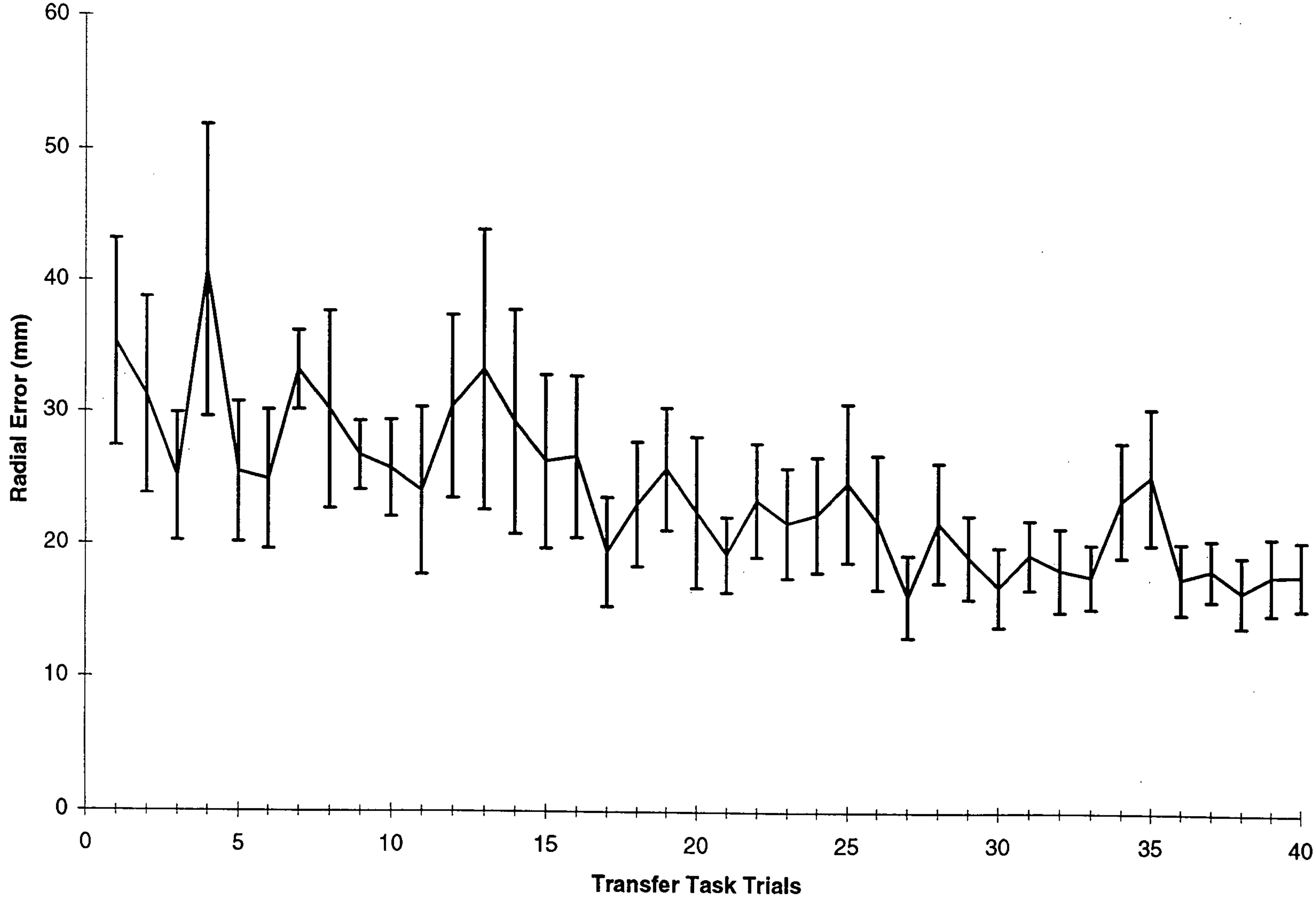
Insert Figures 7 & 8

Three separate t-tests were used to determine the effects of the eye recorder feedback on the subject's ability to fixate on the non-kicking foot throughout the event sequence. The first five trials from the laboratory (phase 4) were compared to the last five trials from the laboratory. These same first five trials (from phase 4) were also compared to the last five trials in the transfer section (phase 7). Finally, the first five trials from the transfer task (phase 7), were also compared to the last five trials in phase 7. Results of these three t-tests revealed that there was a significant decrease in mean radial error across all of these comparisons to a significance level of, $p < .01$. It is evident from these data that the goalkeepers reduced their mean radial error across the laboratory and transfer sessions. Goalkeepers were able to focus their gaze on the non-kicking foot with the help of "the eye track recorder knowledge of results system" used in this experiment.

Radial Error
Figure 7



Radial Error
Figure 8



EXPERIMENT II - DISCUSSION

It is clear from the results of Experiment II that the visual training program improved the goalkeepers' ability to predict the direction of a penalty kick in soccer. The pre-training assessment of these goalkeepers shot stopping ability was very similar to the performance of the World Cup goalkeepers that we used for our initial investigation. The 41 percent prediction accuracy exhibited by the World Cup goalkeepers is similar to the 47 percent prediction accuracy displayed by the subjects in this training program. These statistics provide further support that even expert goalkeepers are not able to accurately predict shot direction without adequate training on using an advanced response cue.

The goalkeepers in this training study responded correctly on 58 percent of the trials during phase 2 of the program, where they continued to use their own strategy to predict penalty kick direction in the laboratory session. Response accuracy increased significantly after the information session where subjects were informed about the reliability of using the shot taker's non-kicking foot as the only response cue to predict shot direction. Subjects improved to 83 percent response accuracy by the final phase of their laboratory training. It is also evident from the results of the study that goalkeepers continued to use this predictive strategy throughout the remainder of their training, as prediction accuracy in the transfer task was 80 percent and in the final phase or post-training assessment remained high at 72 percent.

Reaction time data from the laboratory sessions provided evidence that the goalkeepers adjusted to the information given to them in this training study. The subjects' reaction time in phase two of the program clearly indicated that the goalkeepers continued to predict the direction of the penalty kick using their own strategy. However, after our information session with the goalkeepers, subjects' reaction time increased just like the experimental group from Experiment I. The higher reaction times in phase 3 of the program indicated that subjects were employing the new strategy to predict penalty kick direction and that more advanced cognitive processing was now taking place. Providing the goalkeepers with a reliable response cue which occurred late in the pre-contact sequence had the effect of slowing the subjects' reaction time. The goalkeepers now had to visually focus on the non-kicking foot, wait for this foot to plant (100-150ms prior to contact), determine the shot direction from this foot plant, and initiate movement. After phase 3 of the training program, the goalkeepers reaction times began to decrease as they continued to practice responding to the cue, the placement of the non-kicking foot. However, this reduction in reaction time from phase 3 through phase 6 was not significant.

Radial error data from the eye track system showed that the goalkeepers continued to improve their gaze control or ability to fixate on the shot taker's non-kicking foot throughout the different phases of the program. Goalkeepers reduced the distance of their eye fixations from the location of the non-kicking foot from the laboratory to the transfer session. This reduction in radial error provided support that the subjects continued to improve their ability to fixate on the non-kicking foot throughout the pre-contact sequence of the penalty kick.

Further data from the pre and post-training assessments revealed that the goalkeepers movement time and save percentage did not significantly change. While the goalkeepers predicted the direction of the penalties on 72 percent of the kicks in the post-training assessment, neither their save percentage or movement time improved from the pre-training test. While the visual training improved the goalkeepers cognitive ability to predict penalty kick direction, it appears from the save percentage and movement time data that further training would be required for the goalkeepers to consistently stop shots in the actual penalty kick situation.

GENERAL DISCUSSION

Our analysis on the penalty kick in soccer revealed that even expert goalkeepers (international level) were not successful at correctly predicting the direction of penalty kicks. These experts only responded correctly on 41 percent of the penalties taken in four World Cup competitions (1982-1994). This data was supported by the results of Experiment II. Eight expert goalkeepers (national and international level) which took part in this experiment, only predicted shot direction correctly on 47 percent of the penalties which they faced in the pre-training assessment (Experiment II-phase 1).

A literature search, however, revealed that expert performers in other sports were capable of accurate prediction of ball flight. Abernathy and Russell (1984), Abernathy (1987), and Jones and Miles (1978) reported that expert performers in cricket, squash, and tennis respectively, were able to accurately predict the direction of ball flight in their sports. Furthermore, these three studies indicated that this predictive ability was a result of the expert performers recognizing reliable response cues in their opponents pre-contact or pre-flight sequence. The conclusions of these studies led us to propose that soccer goalkeepers were not consistently recognizing reliable response cues in the penalty taker's approach to the ball.

Based on these research findings, we attempted to determine if there was reliable, pre-contact information in the penalty kick situation which would allow a goalkeeper to more accurately predict the direction of the shot. Extensive analysis led to the conclusion that there were several cues displayed by the shot taker which could lead to accurate direction predictions. The response cues which were investigated included the shot taker's starting position, approach to the ball, forward or backward lean of the trunk, direction of the non-kicking foot, inward or outward rotation of the kicking leg knee, and the point of contact with the ball. Further analysis indicated that of these response cues, the only one that was both reliable and allowed the goalkeepers enough time to respond to the penalty, was the direction of the non-kicking foot.

Experiment I was then designed to test the reliability of this response cue. Results of the experiment indicated the placement of the non-kicking foot was a valid and reliable predictor of the direction a penalty taker shoots. When experienced coaches were given information about the response cue, their prediction accuracy significantly increased. After the intervention in Experiment I, coaches were able to accurately predict the direction of penalty kicks 77 percent of the time.

Due to the encouraging results from Experiment I, a visual training program was created for expert goalkeepers based on the reliability of the direction of the non-kicking foot as a response cue. The training program was designed to teach goalkeepers to visually focus on the non-kicking foot as the penalty taker approached the point of ball contact. The program gave goalkeepers the opportunity to enhance their visual skill both in a laboratory and a gymnasium setting. The effectiveness of this training was based in part on how well these goalkeepers were able to transfer their visual expertise to actual shot stopping in the penalty kick situation.

Perhaps the most innovative aspect of this training program was the use of an ASL SU 4000 eye track recorder to train the subjects to more accurately fixate on the path of the non-kicking foot as the penalty taker approached the ball. Subjects were given visual feedback which revealed both the path of the penalty taker's non-kicking foot and the exact location of where they were looking throughout the pre-contact sequence. The eye track recorder produced radial error data, which was a measure of the distance (in millimeters) between the outfield players non-kicking foot and the position of the eye track cursor. Radial error data indicated that the subjects improved their ability to visually focus on the non-kicking foot path from the laboratory to the transfer task. The goalkeepers were able to reduce their radial error from a mean of 36.5 mm in the laboratory to 17.7 mm in the transfer task.

Experiment II was also able to replicate the response accuracy, reaction time, and movement time data from Experiment I. Phase 2 and Phase 3 of the goalkeeper training program were very similar to the pre and post test of Experiment I. The results of the studies were very comparable despite a different subject group. Both the experimental and the control group performed the laboratory prediction task at a 63 percent accuracy level in the pre-test phase of the experiment. After the intervention, the experimental group increased their prediction accuracy to 77 percent while the control group remained at 63 percent. The goalkeepers in phase 2 of the training program predicted the correct direction on 58 percent of the kicks (lower accuracy than the coaches) but after the intervention, improved their performance to an 83 percent level of accuracy.

Reaction time data from the two experiments indicated that the experimental group of coaches and the goalkeepers were experiencing the demands of an increased level of cognitive processing as they were attempting to recognize the response cue and accurately predict shot direction from this cue. Reaction times for the experimental group of coaches increased significantly (330 to 370ms, pre to post) as did those of the group of goalkeepers (65 to 168ms, phase 2 to phase 3).

Despite all the encouraging results from both Experiment I and Experiment II, the visual training program did not transfer to improved shot stopping in the actual penalty kick situation. It is important to note that response accuracy (amount of correct predictions) did maintain a high accuracy level of 80 percent in the transfer task (phase 7) and 72 percent in the post-training assessment (phase 8).

The reason that the improved response accuracy did not result in improved shot stopping ability is that the training program did not decrease the goalkeeper's movement times (time to intercept the path of the ball) in phase 8 from the pre-test assessment (phase 1). The goalkeepers in Experiment II were still hampered by the increased cognitive demands of recognizing and responding to the cue, the placement of the non-kicking foot. These increased demands were great enough that their horizontal movements consistently just failed to intercept the path of the ball. The goalkeepers also appeared to be less confident in the response cue when facing actual penalty kicks and this additionally slowed their movement times. The goalkeepers had employed their own strategy to stop penalty kicks through more than ten years of playing experience and as they faced actual penalty kicks (phase 8), they had a more difficult time attending and responding to the placement of the non-kicking foot. However, the program did achieve the critical objective of improving the goalkeepers' ability to accurately predict the direction of a penalty kick, throughout each of the phases of the training (phase 3 to 8).

Future research in this area should attempt to continually reduce the goalkeepers reaction time while maintaining the high level of prediction accuracy reported in these two experiments (by utilizing the reliable response cue). The laboratory training (phases 2 to 6) in Experiment II failed to reduce the goalkeepers reaction time to a sufficient level where they could consistently stop penalty kicks. An alternative explanation for the slow movement times of the goalkeepers during the post-test (phase 8) was their failure to initiate movement quickly enough. After reacting to the stimulus and predicting the shot direction, the subjects must initiate an "internal go" signal. The time between recognition of the response cue and this internal go signal must also be reduced if goalkeepers' movements are going to be quick enough to stop a penalty kick. Perhaps the next attempt to design a program to improve a goalkeeper's performance in the penalty kick situation, should add a component of physical training which would improve both reaction time as well as the speed with which the goalkeeper is able to initiate their "go signal" and move horizontally to intercept the path of the ball.

REFERENCES

Abernathy, B. & Russell, D.G. (1984). Advance cue utilization by skilled cricket batsmen. Australian Journal of Science and Medicine in Sport, 16, 2-10

Abernathy, B. (1987). Selective attention in fast ball sports 1. General principles Australian Journal of Science and Medicine in Sport, 19, 7-16.

Bransford, J.D. Franks, J.J., Morris, C.D.., & Stein, B.S. (1979). Some general constraints of learning and memory research. In L.S. Cermak & F.I.M. Craik (eds.), Levels of Processing in Human Memory. Hilldale, NJ: Erlbaum, (pp. 331-354).

Burroughs, W. (1984). Visual simulation training of baseball batters. International Journal of Sport Psychology, 15, 117-126.

Chamberlin, C. & Coelho, A. (1993). The perceptual side of action: Decision making in sport. In J.L. Starkes and F. Allard (eds.), Advances in Psychology: Cognitive Issues in Motor Expertise, 102.

Christina, R., Barresi, J. & Shaffner, P. (1990). The development of response selection accuracy in a football linebacker using video training. The Sport Psychologist, 4, 11-17.

Higgins, J.R. & Angel, R.W. (1970). Correction of tracking errors without sensory feedback. Journal of Experimental Psychology, 84, 412-416.

Jones, C.M. & Miles, T.R. (1978). Use of advanced cues in predicting the flight of a lawn tennis ball. Journal of Human Movement Studies, 4, 231-235.

Kuhn, W. (1988). Penalty kick strategies for shooters and goalkeepers in T. Reilly, A. Lee, K. Davids, & W. Murphy (eds.), Science and Football. E & FN Spon: London (pp-552-557).

McMorris, T., Copeman, R., Corcoran, D., Saunders, G., & Potter, S. (1993). Anticipation of soccer goalkeepers facing penalty kicks. In T. Reilly, J. Clarys & A. Stibbe (eds.). Science and Football II. E & FN Spon: London, (pp.250-53)

McMorris, T. & Hauxwell, B. (personal communication). Improving anticipation of soccer goalkeepers using video observation.

Rushall, B.S. (1977). Two observation schedules for sporting and physical education environments. Canadian Journal of Applied Sport Science, 2, 15-21.

Salmela,J.& Fiorito, P. (1979). Visual cues in ice hockey goaltending. Canadian Journal of Applied Sport Sciences, 4, 56-59.

Schmidt, R.A. & Gordon, G.B. (1977). Errors in motor responding, rapid corrections and false anticipations. Journal of Motor Behavior, 9, 101-111.

Starkes, J. (1987). Skill in field hockey: The nature of the cognitive advantage. Journal of Sport Psychology, 9, 146-160.

Thiffault, C. (1974). Tachiostoscopic training and its effects upon visual perceptual speed of ice hockey players. Proceedings of Canadian Association of Sport Sciences, Edmonton, Alberta: University of Alberta.

Vickers, J.N. (1985). Gaze control in basketball foul shooting. In J.M. Findley et al. (eds.) Eye Movement Research. North Holland: Amsterdam, (pp. 283-296).

Williams, A. & Burwitz, L. (1993). Advance cue utilization in soccer. In T. Reilly, J. Clarys & A. Stibbe (eds.) Science and Football II. E & FN Spon: London, pp. 239-43.