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# The effects of stroboscopic training on ball-catching performance

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## Abstract

A visual enhancement training program utilizing stroboscopic lighting was evaluated. Pre-training, training, and post-training sessions were conducted and analyzed to inspect the effects of stroboscopic lighting on catching tennis balls being propelled from a tennis ball machine. The ball catching ability of forty-one high school baseball athletes was assessed using a qualitative scale and a quantitative scale in both pre-training and post-training sessions. The subjects were matched by abilities following the pre-training session into a control group or an experimental group, based on their qualitative score. Contrary to our hypothesis, it was concluded that those athletes in the control group (no stroboscopic training) demonstrated a significantly greater improvement than the experimental group (stroboscopic training), based on the difference between their pre-training and post-training scores. Our data revealed three factors that appcar to be important in ball-catching: stereoacuity, cross dominance, and the level of competition. Future questions as to optimal training conditions under stroboscopic lighting need to be addressed.

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## Keywords

Stroboscopic lighting, stereoacuity, cross dominance

## Subject Categories

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# THE EFFECTS OF STROBOSCOPIC TRAINING ON BALL-CATCHING PERFORMANCE

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**ABSTRACT**

**A** visual enhancement training program utilizing stroboscopic lighting was evaluated. Pre-training, training, and post-training sessions were conducted and analyzed to inspect the effects of stroboscopic lighting on catching tennis balls being propelled from a tennis ball machine. The ball catching ability of forty-one high school baseball athletes was assessed using a qualitative scale and a quantitative scale in both pre-training and post-training sessions. The subjects were matched by abilities following the pre-training session into a control group or an experimental group, based on their qualitative score. Contrary to our hypothesis, it was concluded that those athletes in the control group (no stroboscopic training) demonstrated a significantly greater improvement than the experimental group (stroboscopic training), based on the difference between their pre-training and post-training scores. Our data revealed three factors that appear to be important in ball-catching: stereoacuity, cross dominance, and the level of competition. Future questions as to optimal training conditions under stroboscopic lighting need to be addressed.

Key Words: Stroboscopic lighting, stereoacuity, cross dominance

## INTRODUCTION

In the past, strobe lights have been suggested for clinical use to enhance visual performance. Individuals who received this stroboscopic training reported a phenomenal experience that a task such as ball-catching seemed easier after training. Some commented that the object seemed to move in slower motion, and/or appeared much larger after training. We viewed this as a very intriguing aspect of optometric vision training and wanted to experimentally determine if these phenomenal effects really exist, and if so, can they be measured in a task such as ball-catching. We have been unable to find any published laboratory or clinical evidence to support this phenomenon.

Stroboscopic lighting might be used to enhance the ability to more accurately anticipate the future location of an object. Light and dark periods of vision are created under stroboscopic lighting conditions. One must predict the future location of an object while it is passing through the dark phase of stroboscopic lighting in order to accurately track the trajectory of the object. Stroboscopic lighting may thus present a training environment for enhancement of the visual requirements for tracking a ball.

The authors feel when catching a ball under stroboscopic lighting one must learn to process visual information faster than with constant lighting since the dark period of the strobing does not allow for visual information collection. More accurate eye movements are needed so that visual information can be integrated efficiently. By accurately following the ball and efficiently processing the information a precise motoric response can be made to catch the ball. Therefore, good oculomotor ability is necessary for precision in dynamic visuo-motor tasks.

Research has taken place concerning the relationship between eye movements and ball-catching and hitting. Hubbard and Seng (1954) filmed college and professional baseball hitters in game and practice situations. They found that in visually tracking the ball, the hitters used pursuit eye movements and held their heads fixated. The tracking, however, stopped when the ball was 8 to 15 feet from the plate. They believed it was because either no more information is provided after this point, or because pursuit movements break down at such a high velocity. Bahill et al (1981) furthered this idea. They stated that baseball and tennis players do not "keep their eye on the ball" and that it is physiologically impossible to do so. They hypothesized (and supported with research) that while the head is fixated, the athletes track the ball over the first portion of its trajectory, guess its future position, make a quick saccadic eye movement to this predicted location, and then resume tracking.

Later Bahill and La Ritz (1984) suggested that hitters do not use vergence eye movements. They stated and supported with data, that vergence eye movements are not utilized to track a ball between 60 feet and 6 feet from the plate, since there is an insufficient amount of time to make vergence movements. They suggest that a hitter who actually sees the ball hit the bat must be using monocular vision, and that only the preferred eye tracks the ball (Bahill and La Ritz 1984). If this is true, it may be to a hitter's advantage to have cross dominance. Bahill and La Ritz conclude that success in following a ball is due to laster smooth pursuit eye movenlents, a good ability to suppress the vestibule-ocular reflex, and the occasional use of an anticipatory saccade. The size and timing of the predicted saccade varies with the individual (La Ritz, Hall, and Bahill 1983).

Stroboscopic training may enhance the ability to more accurately anticipate the future location of a tossed ball for the purpose of making a catch. Such enhancement may occur through development of greater precision in oculomotor control.

## METHODS AND PROCEDURES

Forty-six male high school baseball players were recruited from five local high schools. Their ages ranged from 14 to 19 years with a mean age of 16.5 years. All forty-six completed the screening and pre-training procedures. Five subjects were unable to return for the second session (training and post-training), and one subject failed our screening requirements, leaving an experimental n=40. Subjects were told they would be asked to catch tennis balls projected from a tennis ball machine in a squash court. The balls would be directed to five different areas about their body. No ball gloves would be allowed as they would be catching the tennis balls bare-handed. They were told protective eyewear would be provided and would be worn during testing and training. As incentive, each subject earned ten cents per catch for their high school athletic fund, with 50 catches possible. All subjects also received a certificate for a free vision examination at a Pacific University Family Vision Center (a $42.00 value).

All screening, testing, and training took place at the Pacific University Athletic Center in Forest Grove, Oregon. A regulation squash court was utilized for the ball-catching portions of the research. Illumination was provided by fluorescent overhead lighting (48 foot-candles) during testing sessions and by fluorescent or strobe lighting during training sessions.

Data collection for each participant occurred during two separate experimental sessions. The first session consisted of screening tests followed by a pre-training session. The second session consisted of a training session followed by a post-training session. The experimental group trained with stroboscopic lighting while the control group trained with constant standard overhead lighting. The pre-training session and post-training sessions were identical in all respects.

During the first visit, a vision screening was conducted prior to participation. The inclusion criteria consisted of:

1) Demonstrated stereopsis at 40 cm as measured by the Titmus circles in the Randot stereo test
2) Static VA of 20/30 or better OU as measured by a 10 foot Sloan chart

Sighting eye preference was also determined by using the Sighting Eye Test (placing right hand over left and creating a hole to view through at the notch between the thumb and index fingers, raise extended arms from the thigh to eye level, occlude eyes to find preferred eye, and then repeat with left hand over right hand).

Upon completion of the screening procedure, the subjects were given eyewear and instructional sets. They were told to catch as many tosses as possible, with one or two hands. The subjects stood near the front wall (facing the back wall). Taped onto the floor below them were three different colored squares (Figure #1). The subjects would straddle these colored squares to allow the tennis balls to be directed to five different positions relative to their body (Figure #5). The five positions were: to the left, right, and middle of the body at the waist line; and to the body's midline at knee level and just above the head. Five balls were directed to each of the five positions (Figure #5) at a speed of approximately *26* mph, for a total of twenty-five tosses. The subject began with six calibration tosses (three to the left and three to the right) followed by the sequence of test tosses.

**All** pre-training and post-training sessions were videotaped for qualitative analysis at a later time. Analysis was based on the following six point scale:

| Points | |
|---|---|
| 0 | Did not touch ball in attempt to catch it |
| 1 | Touched ball but with no chance to catch it |
| 2 | Touched and almost caught |
| 3 | Extreme bobble but made catch |
| 4 | Slight trouble in making catch |
| 5 | Clean catch |

A quantitative analysis was recorded during the research by an impartial observer as either a catch or a miss. Subjects were matched based upon their pre-training qualitative ball-catching scores and divided into control and experimental groups.

Subjects returned several days later for their training and post-training sessions. The training session consisted of seventy-five possible catches (fifieen at each of the five locations about the body). The control group trained with normal room illumination, while the experimental group trained with stroboscopic lighting (approximately 700 cpm). A reduced ball velocity (approximately 15 mph, setting #5) was used for both the control group and the experimental group. This speed was set arbitrarily slower to decrease the difficulty in catching a ball under the conditions of stroboscopic lighting.

The post-training session began immediately after the tennis ball machine was reloaded and the ball velocity was increased to the pre-training level (approximately 26 mph, setting #3). This post-training session was identical in every manner to the pre-training session (ball velocity, illumination, number of tosses, location of tosses, and sequence of tosses).

The equipment set-up was identical for all testing and training sessions. The equipment employed consisted of four Super Strobe model 1091 lights (Figures #1 & 2) connected to a synchronization unit, so that all would strobe at a simultaneous rate of approximately 700 cpm. This frequency was arbitrarily chosen after experimenting with different rates. The tennis ball machine was placed at the back wall of the squash court (Figure #1). Fifty-four new Wilson tennis balls were propelled toward the subjects at a rate of one toss every 4.5 seconds. An adjustable bracket was utilized as a calibration stop for the vertical movement of the tennis ball machine nozzle (Figures #3 & 4). A video camera (Figure #1) was used to tape the subjects during all pre-training and post-training sessions. Each subject wore protective eyewear (Leader New Yorker for non-spectacled subjects and a Mity Guard sport eyeguard cage for spectacled subjects) and was offered an athletic hard plastic supporter.

The tennis ball machine has a nozzle for directing the projected balls. The machine was set-up so that no horizontal movement of the machine was possible, only a vertical adjustment device for heighth of the projected ball for high and low tosses (Figure #6). By having the subject move laterally after each set of five tosses and straddling the three different colored squares, we were able to direct the balls to the five positions.

Three impartial individuals operated the instrumentation. One individual ran the video camera. The second individual operated the tennis ball machine in adjusting ball heights and speeds, as well as providing identical instruction sets to all subjects. The third individual recorded catches and misses for all subjects, and cleaned the protective eyewear. The experimenters were seated in chairs at or near the back wall of the squash court, with the subject positioned near the front wall.

## RESULTS

Statistical comparisons were completed in order to determine the presence of training effects within and between groups. The control group demonstrated a significantly greater improvement in the number of catches from the pre-training to the post-training sessions ($t=2.33$, $df=37$, $p<0.05$). Also, the control group made a significantly greater number of successful training catches ($t=20.0$, $df=37$, $p<0.01$); *(See* Table #1).

The relationship between stereoacuity and ball catching performance revealed two interesting tendencies. Stereoacuity scores were divided into two subsets. Group A had stereoacuity of less than or equal to 40 arc seconds, while group B had stereoacuity greater than 40 arc seconds. When comparing the pre-training number of catches and the pre-training graded scores there were no significant effects based upon stereoacuity or assignment(experimental or control) group (Graph #1 and Table #4). A comparison of the number of catches and the graded scores on post-training showed that the experimental group tended to score less, but not at a statistically significant level, on both scales and the subjects in the experimental group with poorer stereoacuity (group B) did the worst of all the groups. When comparing the difference in the number of catches and the difference in the graded scores on the post-training task, the subjects in group B (the poorer stereo group) actually showed that the stroboscopic training had a deleterious effect upon catching performance, although not at a statistically significant level (Graph #2 and Table #4).

The second tendency regarding stereoacuity was a difference in the number of catches and a difference in the graded score based on stereoacuity. The subjects in group A improved from pre-training to post-training on both qualitative and quantitative scales about three times more than those subjects in group B (Graph #3).

The relationship between cross dominance and ball catching was also investigated. The subjects who were cross dominant, having their preferred sighting eye opposite of their dominant hand, demonstrated poorer stereoacuity ($x=79.1$ arc seconds, $n=11$) in our study when compared to the subjects who were not cross dominant ($x=49.5$ arc seconds, $n=28$; $df=37$, $t=-2.24$, $p<0.05$). Despite this, the cross dominant subjects tended to do better on both pre-training and post-training tasks (Graph #4).

The last area that we examined involved a comparison between schools. On both qualitative and quantitative scales for both pre-training and post-training tasks, the school with the highest enrollment (GL), which also competes in a metropolitan league that is highly competitive, scored the highest in each of the categories (Table #5).

In all of our comparisons, age had no statistically significant influence on any of the factors studied.

## DISCUSSION

Our research explored the use of stroboscopic lighting to enhance a ball catching task. It is our hope that this area of research will be expanded, so that a better understanding of stroboscopic lighting and its training effects will assist others in future visual therapy and sports vision training.

Although our initial hypothesis was not statistically supported by our data, we feel there were several results that will be helpful to researchers and clinicians in the future. The most important of these involved the number of catches during the training session. There were a total of seventy-five catches possible and the control group averaged 69.1 catches while the experimental group averaged only 18.3 catches. We feel that the strobe frequency used in the training session presented a task level that was too difficult, and thus the experimental group did not benefit from the motor reinforcement of repeatedly catching tennis balls as occurred with the control group. The optimal strobe frequency for training of this kind has not been determined.

Our data also showed three factors that need to be considered in future research: stereoacuity, cross dominance, and the level of competition.

The data involving stereoacuity suggest that before beginning stroboscopic training, one should take measures to maximize stereoacuity to obtain the best results (Graphs #1 & 2). The strobe light caused less performance decrement in those experimental subjects in group **A,** the group with the better stereoacuity (Graph #2). The pre-to-post difference in the number of catches and pre-to-post difference in graded score based upon stereoacuity (Graph #3) also support the approach that one may wish to maximize stereoacuity before beginning more advanced training techniques.

Cross dominance should be considered when training athletes involved in ball catching tasks. It appears that the cross dominant subjects in our study tended to be better ball catchers. If stereoacuity had been maximized in the cross dominant subjects, one might have seen an even greater difference when comparing pre-training and post-training performance (Graph #4).

The third factor involved level of competition. As mentioned before, the school with the highest enrollment, which also competes in a metropolitan league that is highly competitive, scored the highest in each of the categories investigated (Table #5). These data suggest that the level of competition should be considered in future research involving stroboscopic lighting and athletic performance.

Many questions remain in our minds concerning optimal testing/training conditions. What is the optimal stroboscopic frequency for training, and does it have any relationship to other aspects of human performance? How long should a stroboscopic training session last, and how frequently should one train in order to measure beneficial or detrimental effects? What ball speed, alone or relative to strobe frequency, is optimal for training ball-catching abilities? Ball size and color should also be examined. We are uncertain as to how long to wait in testing for the effects of stroboscopic training. Is it better to immediately test for training effects, or is it best to wait a certain amount of time? How long do the stroboscopic training effects remain with an individual? These questions and others need to be addressed in future research.

## CONCLUSION

We recognize that our study was a pilot study with many variables and limitations. Although our initial hypothesis was not supported by our data, we feel that this study has provided useful insights and a foundation for further research in studying stroboscopic lighting for visual enhancement. Our data revealed three factors that need to be examined more closely in the future: stereoacuity, cross dominance, and the level of competition. In the future, questions as to optimal training conditions under stroboscopic lighting will need to be addressed.

## FIGURES

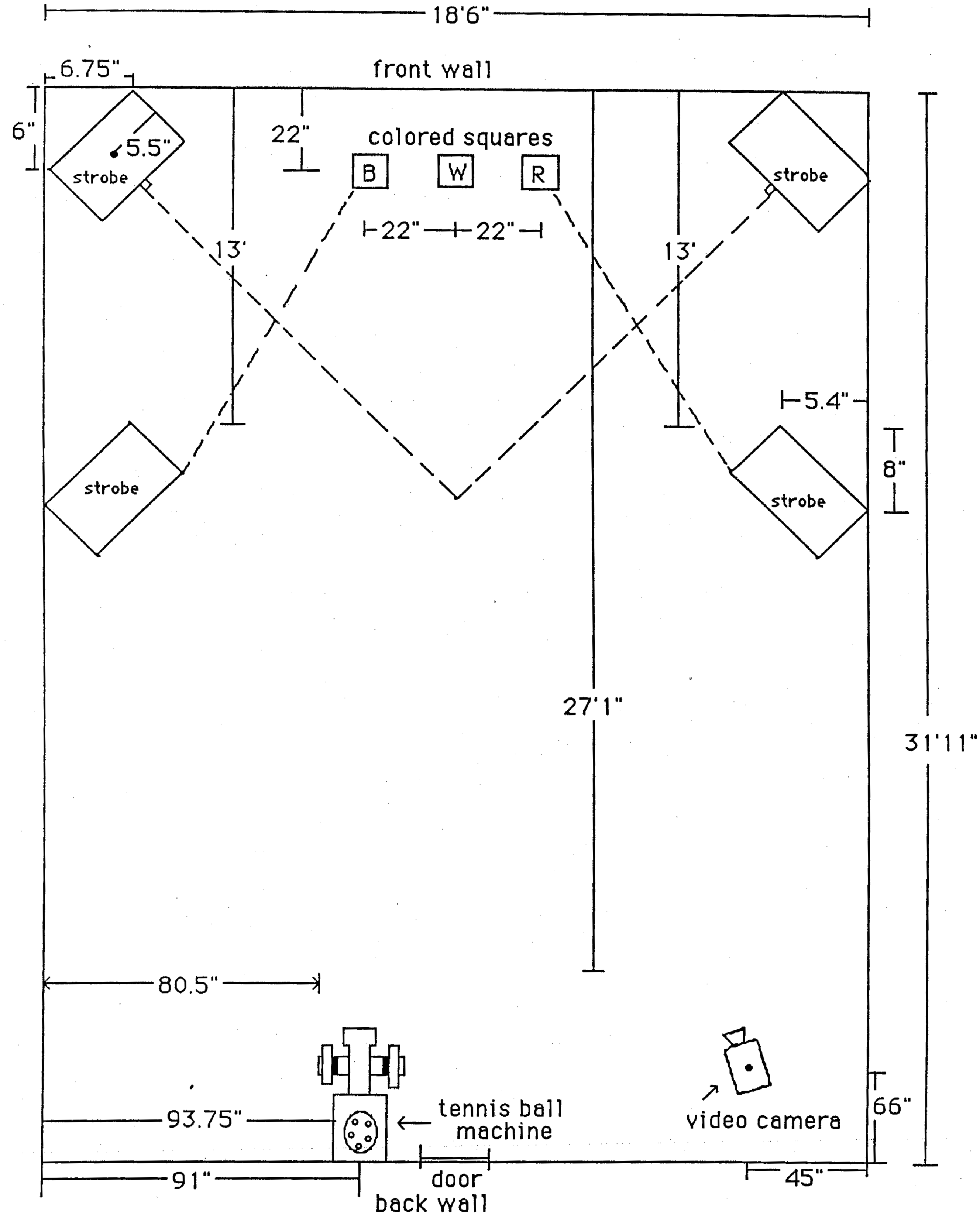



Figure #1 Experimental environment and equipment set-up
(Aerial view of squash court)

Super strobe model 1091

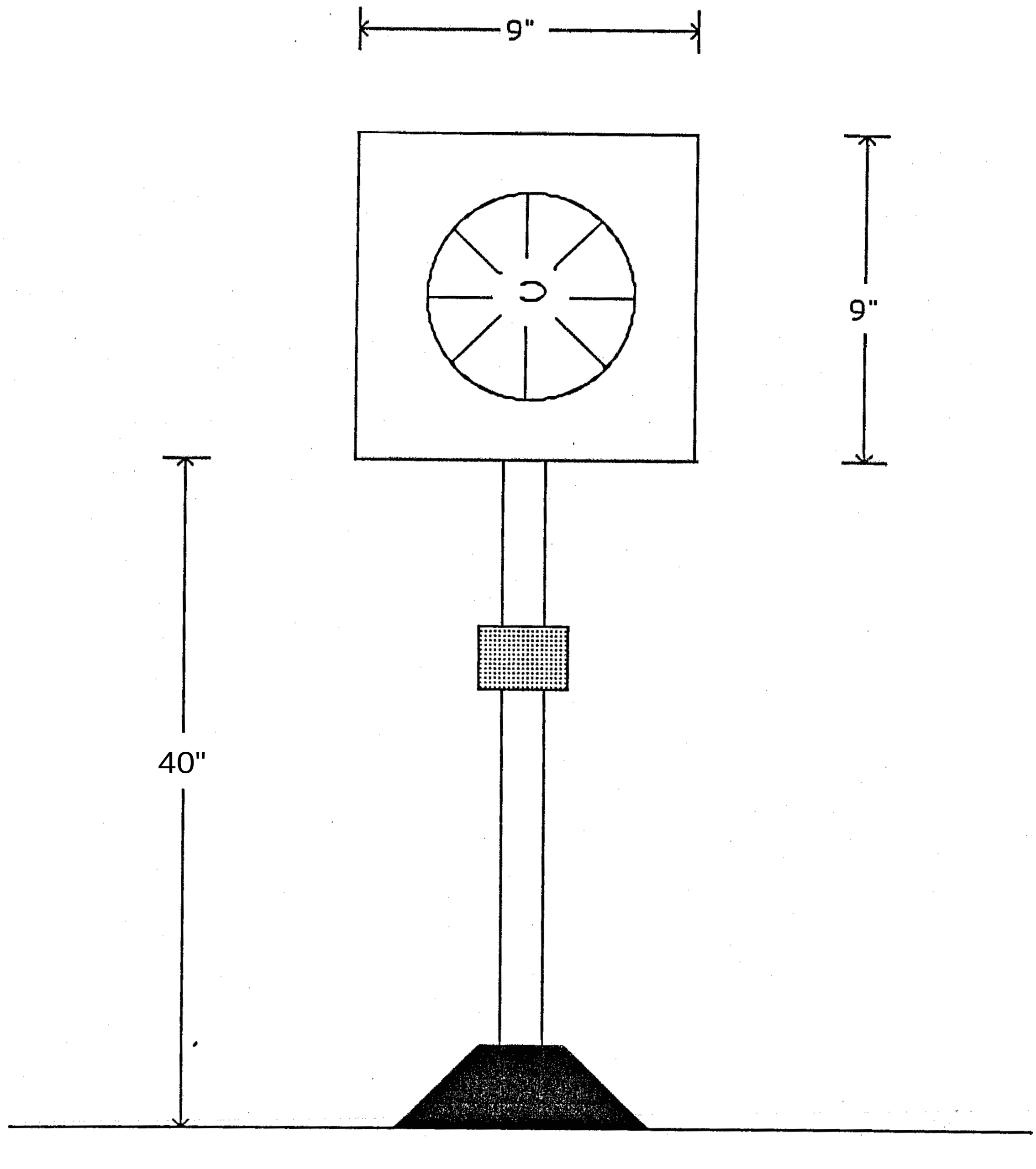



Figure #2 Strobe light and housing
(front view)

Bracket for ball height adjustment

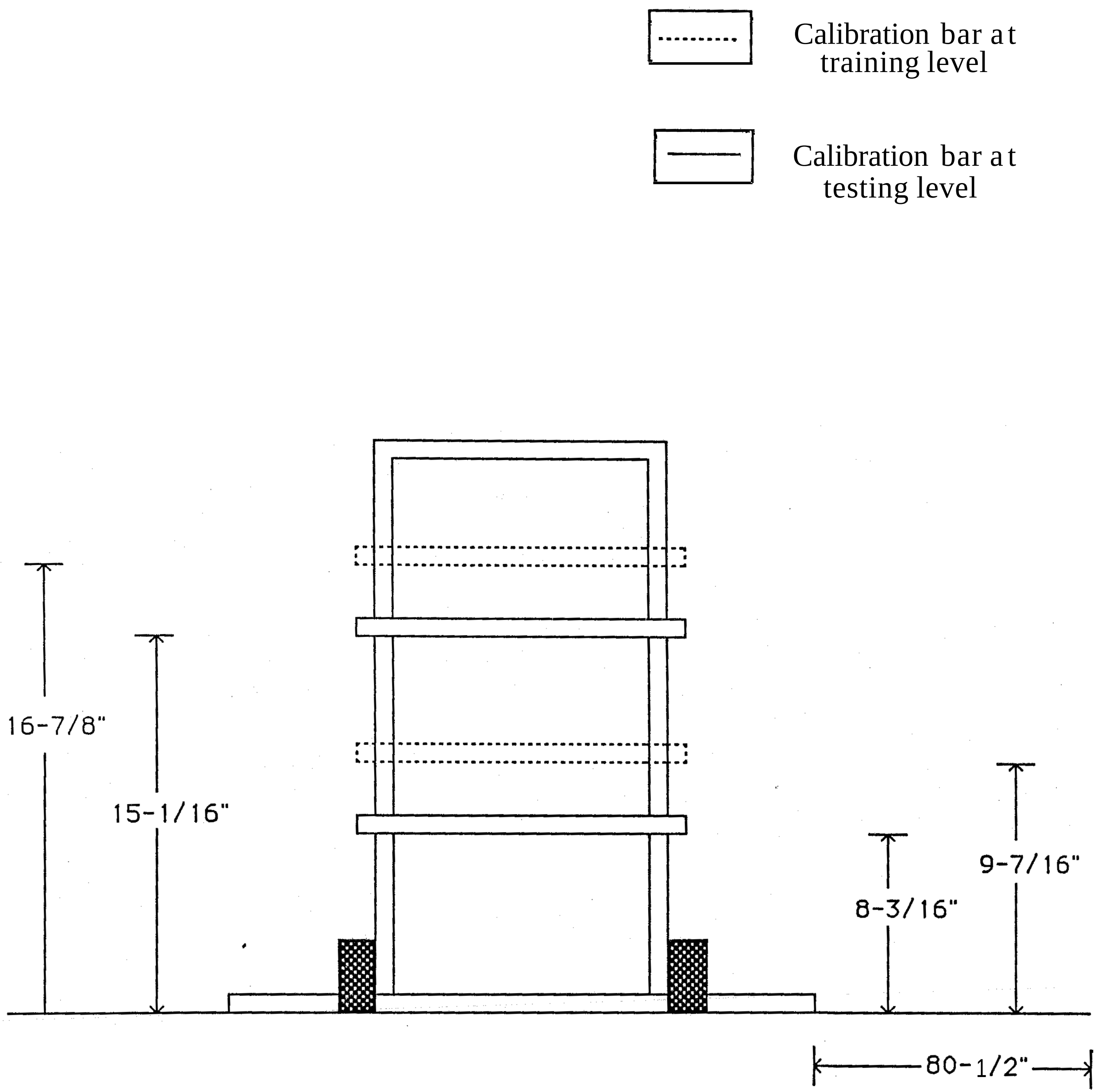



Figure #3 Adjustable bracket for tennis ball machine nozzle (front view)

A = Right of waist line toss
B = Mid waist line toss
C = Left of waist line toss
D = Overhead toss
E = Knee level toss

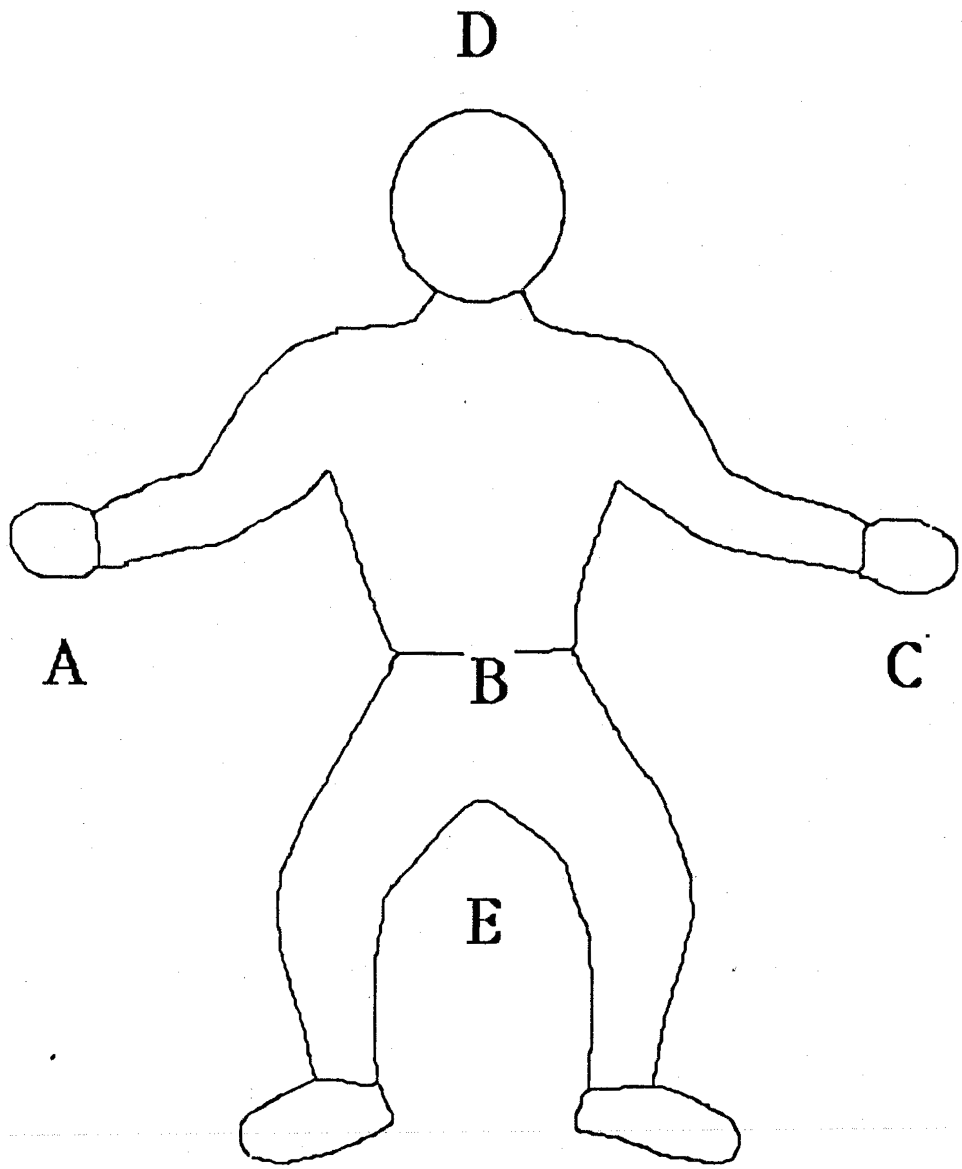



Figure # 5 The five calibration positions for ball placement

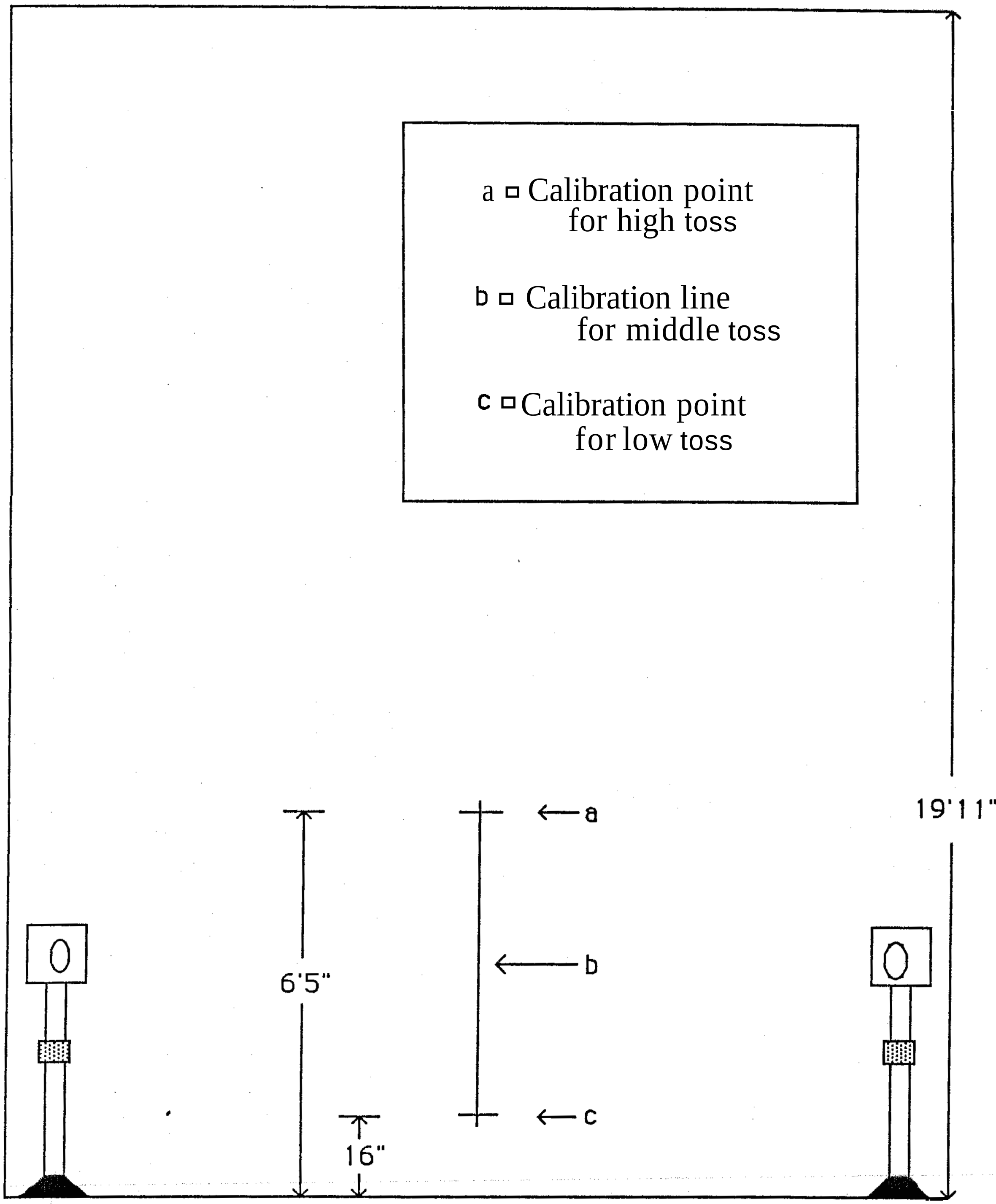
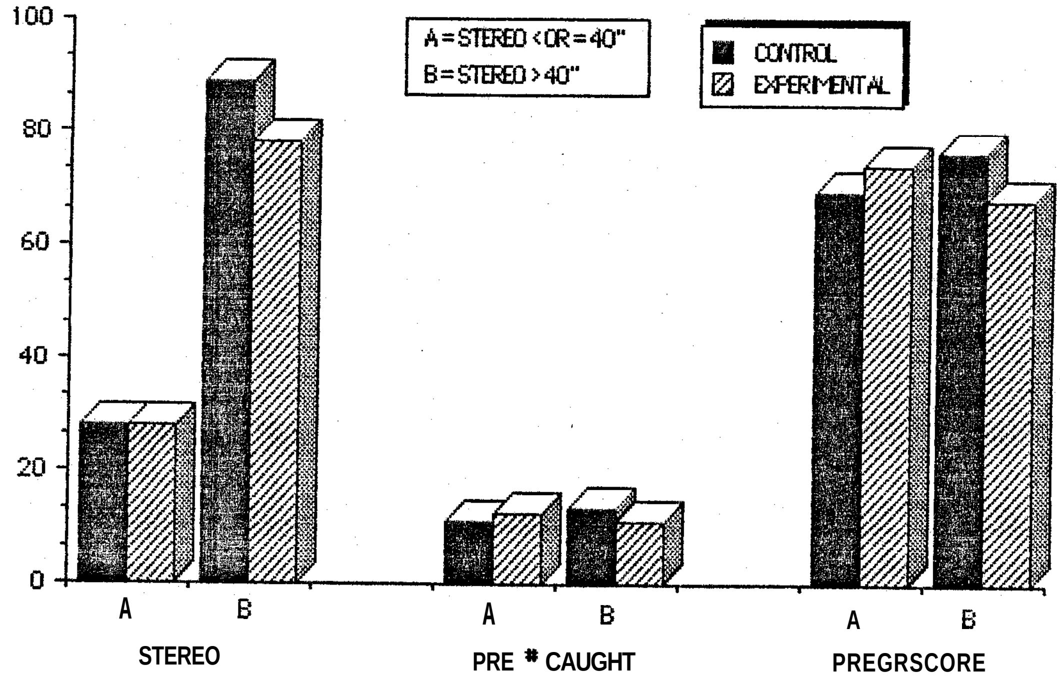
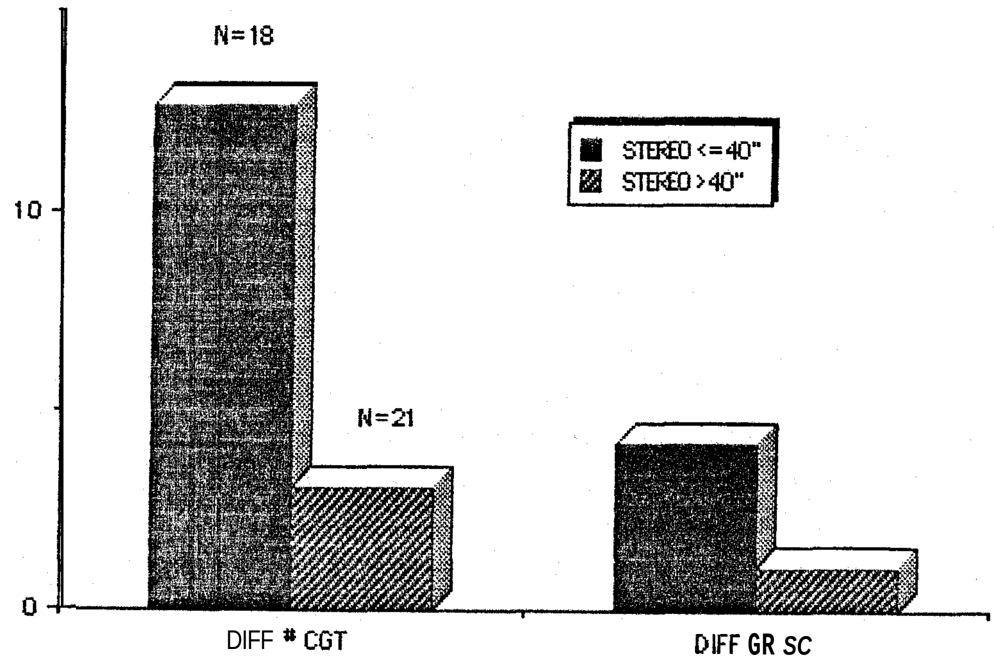



Figure #6 Diagram of front wall (from the back wall) with vertical calibration heights of tennis ball tosses

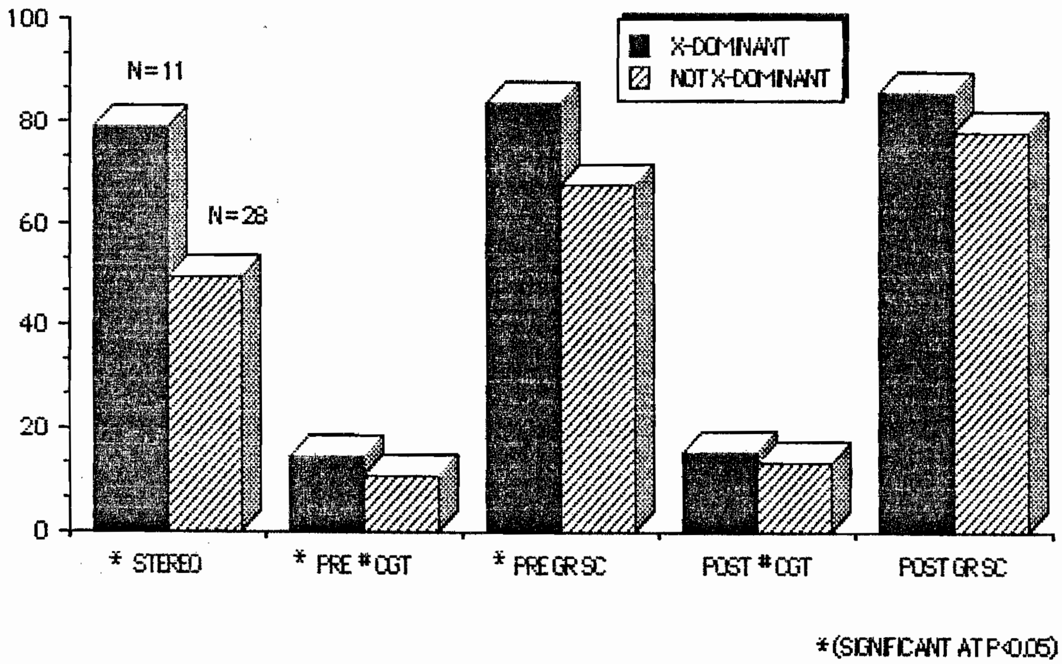
# GRAPHS




GRAPH #1. Comparison of Stereo Acuity and Pre-testing Scores.




GRAPH #3. Comparison of Stereo Acuity and the Post-testing Difference in Scores.




GRAPH #4. Comparison of Ocular Dominance and Stereo Acuity, Pre-testing Scores, and Post-testing Scores.

**TABLES**

| | | | | | |
|---|---|---|---|---|---|
| | **STEREO ACUITY** | | DF= 37 | t= 0.61 | p= .55 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 61.9 | 46.6 | 18 | | |
| EXPERIMENTAL | 54.3 | 32 | 21 | | |
| | | | | | |
| | **PRE-TRAINING NO. OF CATCHES** | | DF= 37 | t= -0.121 | p=.90 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 11.9 | 4.7 | 18 | | |
| EXPERIMENTAL | 12.1 | 5.4 | 21 | | |
| | | | | | |
| | **PRE-TRAINING GRADED SCORE** | | DF= 37 | t= -0.017 | p= .99 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 71.8 | 21.4 | 18 | | |
| EXPERIMENTAL | 72 | 21.8 | 21 | | |
| | | | | | |
| | **POST-TRAINING NO. OF CATCHES** | | DF= 37 | t= 1.997 | p= .053 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 15.9 | 4.2 | 18 | | |
| EXPERIMENTAL | 12.5 | 6.3 | 21 | | |
| | | | | | |
| | **POST-TRAINING GRADED SCORE** | | DF= 37 | t= 1.811 | p= .078 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 86.7 | 18.1 | 18 | | |
| EXPERIMENTAL | 74.2 | 23.9 | 21 | | |
| | | | | | |
| | **DIFFERENCE IN THE NO. OF CATCHES** | | DF= 37 | t= 2.327 | p= .026 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 4 | 3.9 | 18 | | |
| EXPERIMENTAL | 0.3 | 5.6 | 21 | | |
| | | | | | |
| | **DIFFERENCE IN THE GRADED SCORES** | | DF= 37 | t= 2.015 | p= .051 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 14.9 | 16 | 18 | | |
| EXPERIMENTAL | 2.3 | 22 | 21 | | |
| | | | | | |
| | **TRAINING CATCHES** | | DF= 37 | t= 20.0 | p= .00001 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 69.1 | 6.3 | 18 | | |
| EXPERIMENTAL | 18.3 | 9 | 21 | | |
| | | | | | |
| | **AGE** | | DF= 37 | t= -0.085 | p= .93 |
| | | | | | |
| | MEAN | SD | N | | |
| CONTROL | 16.4 | 1.1 | 18 | | |
| EXPERIMENTAL | 16.5 | 1.2 | 21 | | |

TABLE #1. Table of t Values for Control vs Experimental.

| | | | | | |
|---|---|---|---|---|---|
| | **STEREO ACUITY** | | DF= 37 | t= -2.243 | p= .031 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 49.5 | 28.9 | 28 | | |
| CROSS DOMINANT | 79.1 | 53.4 | 11 | | |
| | **PRE-TRAINING NO. OF CATCHES** | | DF= 37 | t= -2.104 | p= .042 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 11 | 5.2 | 28 | | |
| CROSS DOMINANT | 14.6 | 3.4 | 11 | | |
| | **PRE-TRAINING GRADED SCORE** | | DF= 37 | t= -2.186 | p= .035 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 67.4 | 21.9 | 28 | | |
| CROSS DOMINANT | 83.3 | 15.3 | 11 | | |
| | **POST-TRAINING NO. OF CATCHES** | | DF= 37 | t= -0.959 | p= .34 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 13.5 | 5.3 | 28 | | |
| CROSS DOMINANT | 15.5 | 6.5 | 11 | | |
| | **POST-TRAINING GRADED SCORE** | | DF=37 | t= -0.965 | p= .34 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 77.9 | 20.7 | 28 | | |
| CROSS DOMINANT | 85.5 | 25.6 | 11 | | |
| | **DIFFERENCE IN THE NO. OF CATCHES** | | DF=37 | t= 0.91 | p= .37 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 2.5 | 5.3 | 28 | | |
| CROSS DOMINANT | 0.82 | 4.9 | 11 | | |
| | **DIFFERENCE IN THE GRADED SCORES** | | DF=37 | t= 1.15 | p= .26 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 10.4 | 20.7 | 28 | | |
| CROSS DOMINANT | 2.2 | 18.6 | 11 | | |
| | **NO. OF TRAINING CATCHES** | | DF= 37 | t= -0.84 | p= .41 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 39.5 | 26.7 | 28 | | |
| CROSS DOMINANT | 47.5 | 27.4 | 11 | | |
| | **AGE** | | DF= 37 | t= -0.593 | p= .56 |
| | MEAN | SD | N | | |
| NOT CROSS DOMINANT | 16.4 | 1.1 | 28 | | |
| CROSS DOMINANT | 16.6 | 1.2 | 11 | | |

TABLE #2. Table of t Values for Ocular Dominance.

| | | | | | |
|---|---|---|---|---|---|
| | **STEREO ACUITY** | | DF= 37 | t= -6.226 | p= .00001 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 28.1 | 7.7 | 18 | | |
| STEREO > 40" | 83.3 | 36.9 | 21 | | |
| | | | | | |
| | **PRE-TRAINING NO. OF CATCHES** | | DF= 37 | t= 0.448 | p= .66 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 12.4 | 5.7 | 18 | | |
| STEREO > 40" | 11.7 | 4.4 | 21 | | |
| | | | | | |
| | **PRE-TRAINING GRADED SCORE** | | DF= 37 | t= 0.369 | p= .71 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 73.3 | 24.4 | 18 | | |
| STEREO > 40" | 70.7 | 18.9 | 21 | | |
| | | | | | |
| | **POST-TRAINING NO. OF CATCHES** | | DF= 37 | t= 1.488 | p= .15 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 15.5 | 4.5 | 18 | | |
| STEREO > 40" | 12.9 | 6.3 | 21 | | |
| | | | | | |
| | **POST-TRAINING GRADED SCORE** | | DF= 37 | t= 1.586 | p= .12 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 85.9 | 18.3 | 18 | | |
| STEREO > 40" | 74.9 | 24.2 | 21 | | |
| | | | | | |
| | **DIFFERENCE IN THE NO. OF CATCHES** | | DF= 37 | t= 1.154 | p= .26 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 3.1 | 5.6 | 18 | | |
| STEREO > 40" | 1.1 | 4.7 | 21 | | |
| | | | | | |
| | **DIFFERENCE IN THE GRADED SCORES** | | DF= 37 | t= 1.316 | p= .20 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 12.7 | 21.8 | 18 | | |
| STEREO > 40" | 4.2 | 18.5 | 21 | | |
| | | | | | |
| | **NO. OF TRAINING CATCHES** | | DF= 37 | t= -0.045 | p= .96 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 41.6 | 26.2 | 18 | | |
| STEREO > 40" | 42 | 27.9 | 21 | | |
| | | | | | |
| | **AGE** | | DF= 37 | t= -0.643 | p= .52 |
| | | | | | |
| | MEAN | SD | N | | |
| STEREO <= 40" | 16.3 | 1.3 | 18 | | |
| STEREO > 40" | 16.6 | 1 | 21 | | |

TABLE #3. Table of t Values for Stereo Acuity Comparisons.

| | N | STEREO ACUITY | PRE-TRAINING NO. OF CATCHES | PRE-TRAINING GRADED SCORE | |
|---|---|---|---|---|---|
| CONTROL/GROUP A | N=8 | 28.1 | 11.25 | 69.3 | |
| EXPERIMENTAL/GROUP A | N=10 | 28 | 13.4 | 76.5 | |
| CONTROL/GROUP B | N=10 | 89 | 12.5 | 73.9 | |
| EXPERIMENTAL/GROUP B | N=11 | 78 2 | 11 | 67.8 | |
| | | POST-TRAINING NO. OF CATCHES | POST-TRAINING GRADED SCORE | DIFFERENCE IN THE NO. OF CATCHES | DIFFERENCE IN THE GRADED SCORE |
| CONTROL/GROUP A | N=8 | 15.9 | 87 | 4.6 | 17.8 |
| EXPERIMENTAUGROUPA | N=10 | 15 2 | 85.1 | 1.8 | 8.6 |
| CONTROL/GROUP B | N=10 | 16 | 86.5 | 3 5 | 12.6 |
| EXPERIMENTAL/GROUP B | N=11 | 10 | 64.4 | - 1 | -3.5 |
| | | | | GROUP A = STEREO < 40" | |
| | | | | GROUP B = STEREO > 40' | |

**TABLE X4. Table of Values for Graphs #1 and #2**

| | NUMBER IN GROUP | STEREO | PRE-TRAIN # OF CATCHES | PRE-TRAIN GRADED SCORE |
|---|---|---|---|---|
| **SCHOOL** | | | | |
| FG | 12 | 51.3 | 12.4 | 75.1 |
| H | 5 | 54 | 12 | 72.2 |
| B | 10 | 43 | 10.2 | 62.2 |
| GA | 3 | 63.3 | 4.7 | 39 |
| a | 9 | 83.3 | 16.1 | 89.2 |
| | POST-TRAIN # OF CATCHES | POST-TRAIN GRADED SCORE | | |
| SCHOOL | | | | |
| FG | 12.1 | 73.8 | | |
| H | 12.4 | 73.6 | | |
| B | 13.5 | 76.1 | | |
| GA | 14 | 78.3 | | |
| a | 18.3 | 96.7 | | |
| | | | * All numbers reported as a mean value. | |

TABLE #5. Comparison of Schools.

| | | | | PRE-TEST DATA | | | POST-TEST DATA | | PRE/POST CHANGE | | TRAINING | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB.# | NAME | VA OU | STEREO | #CAUGHT | GRADED SC. | GROUP | #CAUGHT | GRADED SC. | #CAUGHT | GRADED SC. | CATCHES | | CORRECTION | DOM. HAND | DOM. EYE | SCHOOL | AGE | EYEWEAR |
| 1 | W.F. | 20/20-2 | 30" | 19 | 103 | C | 21 | 114 | 2 | 11 | 73 | | N | R | OD | FG | 16 | NY |
| 2 | D.K. | 20/15-1 | 20" | 19 | 103 | X | 12 | 74 | -7 | -29 | 27 | | N | R | OD | FG | 18 | NY |
| 3 | B.R. | 20/15-1 | 70" | 2 | 34 | X | 2 | 32 | 0 | -2 | 5 | | N | R | OD | H | 17 | NY |
| 4 | J.C. | 20/15 | 40" | 10 | 70 | C | 18 | 95 | 8 | 25 | 72 | | N | R | OD | FG | 17 | NY |
| 5 | J.B. | 20/20-1 | 30" | 13 | 76 | X | 21 | 105 | 8 | 29 | 25 | | N | L | OD | H | 19 | NY |
| 6 | T.B. | 20/20-1 | 70" | 14 | 79 | X | 19 | 98 | 5 | 19 | 14 | | N | R | OD | H | 17 | NY |
| 7 | J.BO. | 20/25-1 | 100" | 7 | 50 | X | 6 | 49 | -1 | -1 | 8 | | 3A | L | OS | B | 17 | NY |
| 8 | L.L. | 20/25 | 70" | 10 | 65 | C | 19 | 100 | 9 | 35 | 70 | | 3A | R | OD | B | 16 | NY |
| 9 | B.K. | 20/20+3 | 70" | 14 | 82 | X | 18 | 100 | 4 | 18 | 23 | | N | R | OD | FG | 15 | NY |
| 10 | E.V. | 20/20-1 | 20" | 10 | 66 | X | 13 | 73 | 3 | 7 | 28 | | N | R | OD | B | 17 | NY |
| 11 | D.C. | 20/15-2 | 20 | 17 | 88 | X | 14 | 78 | -3 | -10 | 18 | | N | R | OD | B | 17 | NY |
| 13 | J.U. | 20/15-2 | 70" | 14 | 81 | X | 12 | 69 | -2 | -12 | 19 | | N | R | OD | FG | 16 | NY |
| 14 | J.K. | 20/15-2 | 70" | 6 | 47 | X | 9 | 61 | 3 | 14 | 21 | | N | R | OD | FG | 16 | NY |
| 16 | J.O. | 20/20+3 | 30" | 18 | 92 | C | 18 | 97 | 0 | 5 | 73 | | 3A | R | OD | B | 16 | NY |
| 17 | J.H. | 20/15-2 | 70" | 14 | 82 | C | 12 | 72 | -2 | -10 | 74 | | N | L | OS | H | 16 | NY |
| 18 | R.F. | 20/20 | 30" | 5 | 39 | X | 16 | 87 | 11 | 48 | 8 | | N | R | OD | B | 15 | NY |
| 19 | R.A. | 20/15-3 | 20" | 7 | 45 | C | 12 | 64 | 5 | 19 | 70 | | 3A | R | OD | B | 17 | NY |
| 20 | M.M. | 20/20 | 50" | 14 | 80 | C | 18 | 88 | 4 | 8 | 72 | | 3B | R | OD | B | 18 | NY |
| 21 | B.V. | 20/15-1 | 20" | 4 | 37 | C | 11 | 64 | 7 | 27 | 59 | | N | R | OD | B | 16 | NY |
| 23 | B.H. | 20/20 | 30" | 17 | 90 | X | 8 | 61 | -9 | -29 | 20 | | N | R | OD | H | 15 | NY |
| 24 | M.MA. | 20/15-3 | 70" | 13 | 79 | C | 11 | 67 | -2 | -12 | 67 | | 2 | R | OS | FG | 15 | CAGE |
| 25 | T.P. | 20/25-2 | 50" | 12 | 66 | C | 16 | 81 | 4 | 15 | 69 | | 3A | R | OS | FG | 17 | NY |
| 26 | R.B. | 20/15-1 | 70" | 10 | 60 | C | 8 | 54 | -2 | -6 | 69 | | N | R | OD | B | 15 | NY |
| 27 | D.S. | 20/15-2 | 25" | 9 | 61 | X | 9 | 61 | 0 | 0 | 3 | | N | R | OD | FG | 14 | NY |
| 28 | M.G. | 20/15-3 | 20" | 13 | 81 | C | 13 | 78 | 0 | -3 | 67 | | N | R | OS | FG | 15 | NY |
| 31 | B.W. | 20/15 | 25" | 6 | 43 | C | 15 | 80 | 9 | 37 | 67 | | N | R | OD | GA | 15 | NY |
| 33 | R.H. | 20/20-1 | 25" | 5 | 43 | X | 14 | 81 | 9 | 38 | 14 | | N | R | OD | GA | 16 | NY |
| 34 | S.R. | 20/20-3 | 100" | 16 | 89 | C | 21 | 109 | 5 | 20 | 75 | | N | R | OS | GL | 17 | NY |
| 35 | M.ME. | 20/15-1 | 70" | 15 | 86 | C | 20 | 104 | 5 | 18 | 73 | | N | R | OS | GL | 18 | NY |
| 36 | B.G. | 20/15-2 | 40" | 16 | 82 | X | 22 | 111 | 6 | 29 | 25 | | N | R | OD | GL | 18 | NY |
| 37 | C.M. | 20/15-2 | 70" | 18 | 95 | X | 18 | 93 | 0 | -2 | 39 | | N | R | OD | GL | 16 | NY |
| 38 | K.B. | 20/20 | 200" | 18 | 101 | C | 22 | 112 | 4 | 11 | 74 | | N | R | OS | GL | 16 | NY |
| 39 | M.S. | 20/15 | 140" | 15 | 85 | X | 11 | 67 | -4 | -18 | 22 | | N | R | OS | GL | 16 | NY |
| 40 | C.T. | 20/20+2 | 40" | 23 | 117 | X | 23 | 117 | 0 | 0 | 28 | | N | R | OS | GL | 16 | NY |
| 41 | S.S. | 20/15 | 100" | 12 | 71 | X | 3 | 41 | -9 | -30 | 7 | | N | L | OD | FG | 17 | NY |
| 42 | A.S. | 20/20-3 | 50" | 8 | 57 | X | 3 | 42 | -5 | -15 | 15 | | 3A | R | OD | FG | 17 | NY |
| 43 | T.S. | 20/15-2 | 50" | 11 | 65 | X | 9 | 56 | -2 | -9 | 16 | | N | R | OS | GL | 17 | NY |
| 44 | P.R. | 20/15-1 | 140" | 3 | 31 | C | 13 | 74 | 10 | 43 | 49 | | N | R | OD | GA | 19 | NY |
| 46 | M.G. | 20/15-1 | 40" | 13 | 83 | C | 19 | 101 | 6 | 18 | 71 | | N | R | OD | GL | 17 | NY |
| | | | TOTAL = | 470 | 2804 | | 549 | 3110 | | | | | | | | | | |
| | | | AVG = | 12.05 | 72 | | 14 | 80 | | | | | | | | | | |
| | DID NOT MAKE POST-TEST | | | | | | | | | | | | | | | | | |
| 12 | R.B. | 20/15-1 | 25" | 10 | 64 | C | 0 | 0 | 0 | 0 | 0 | | N | R | OD | B | | NY |
| 22 | T.H. | 20/15 | 30" | 7 | 48 | C | 0 | 0 | 0 | 0 | 0 | | N | L | OD | FG | | NY |
| 29 | J.W. | 20/40 | 40" | 3 | 26 | X | 0 | 0 | 0 | 0 | 0 | | N | L | OS | FG | | NY |
| 30 | R.R. | 20/25-2 | 40" | 7 | 51 | C | 0 | 0 | 0 | 0 | 0 | | N | R | OS | GA | | NY |
| 32 | E.H. | 20/15-2 | 70" | 13 | 74 | C | 0 | 0 | 0 | 0 | 0 | | 2 | R | OS | GA | | CAGE |
| | | | TOTAL = | 40 | | | | | | | | | | | | | | |
| | FAILED SCREENING CRITERIA | | | | | | | | | | | | | | | | | |
| 45 | K.C. | 20/20-2 | NEG | 2 | 24 | C | 1 | 22 | | | 14 | | N | L | OS | GA | 16 | NY |
| | | | TOTAL= | 512 | | | 550 | | | | | | | | | | | |
| | | | TOTAL= | 1062 | | | | | | | | | | | | | | |

SABLE #6. Compilation of All Data Collected

## APPENDIX OF EQUIPMENT

"The Little Prince with VSP" (tennis ball machine)
110 volt, 60 Hz, 10 amps

Olympus VHS HQ video camcorder
**VX-403**

Super Strobe
Model 1091
115 volt, 60 Hz, 0.4 amps
maximum 50 watts

DDS-1097 Tube

910 R Signal appliance (synch box)

4 mil black plastic tarp

Sloan acuity chart
3 m letters, LD 10
Good-Lite Company

Randot Stereotests
Stereo Optical Company, Inc.

Leader New Yorker Sport Eyeguard
Polycarbonate lenses
LSP Leader Sport Products Inc.,Essex, N.Y.

Mity Guard Sport Eyeguard Cage
Cucamonga, Calif.

Wilson Championship tennis balls
Extra duty felt (hard court surfaces)
Wilson Sporting Goods Co., River Grove, Ill.

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Banks High School Athletics
Gaston High School Athletics
Glencoe High School Athletics
Forest Grove High School Athletics
Hillsboro High School Athletics
Portland Beavers Baseball Club
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