THE EFFECTS OF YELLOW, ORANGE, AND WHITE BASEBALLS UPON THE VISUAL PERCEPTION AND HITTING EFFECTIVENESS OF COLLEGE BASEBALL PLAYERS

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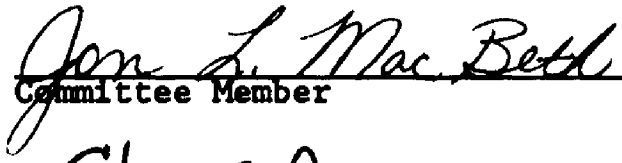

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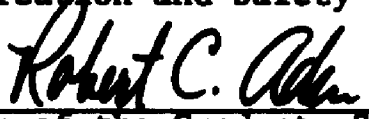

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ABSTRACT

THE EFFECTS OF YELLOW, ORANGE, AND WHITE BASEBALLS UPON THE VISUAL PERCEPTION AND HITTING EFFECTIVENESS OF COLLEGE BASEBALL PLAYERS

by Danny Ross Davis

The purpose of this investigation was to determine the effects of yellow, orange, and white baseballs upon the visual perception and hitting effectiveness of college baseball players. Subjects for the study were five varsity baseball players from David Lipscomb College (Nashville, Tennessee) and fifteen non-baseball playing college male students from Middle Tennessee State University (Murfreesboro, Tennessee).

Data were collected during the spring semester, 1978. Prior to participation in the study, each subject was given a color blindness test and was found to possess normal color perception. All subjects watched ten pitches of each color of baseball thrown by an experienced college batting-practice pitcher and ranked the colors from the most visually perceptible to the least visually perceptible to them.

Each of the college baseball players also swung at thirty pitches of each color of baseball over a period of three trials. Each swing was filmed by a 16 mm high speed movie camera set at 500 frames per second. From this film the effectiveness with which each baseball was hit was determined by comparing the velocity of the ball leaving the bat to the velocity at which the ball was thrown to the batter.

By analysis of variance, there was found to be no significant difference at the .05 level in the effectiveness with which the college baseball players hit the yellow, orange, and white baseballs.

The visual perception rankings of the university students and the college baseball players were analyzed by two nonparametric statistical procedures, the Friedman two-way analysis of variance by ranks and the sign test. No statistically significant difference was found in the rank order preference of either the students or the baseball players for the yellow, orange, and white baseballs. However, the students' visual perception rankings seemed to indicate a trend in the direction of a preference for the yellow and orange balls over the white ball. The yellow and orange baseballs were about equal in the rank order preference of the students, and both of these colors were preferred over the white baseball.

ACKNOWLEDGEMENTS

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In conclusion, the author is indebted to his family, especially to his wife, Cathy, and his mother, Dorothy, who have sacrificed so much for him.

Dedicated to the memory of

Boyd and Don

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Chapter 1

INTRODUCTION

When people are asked to name the senses of the human body, it seems one of the first ones they usually list is sight. Vision is certainly important to us and happens to be one of the most complex of the senses. Numerous studies have been conducted on vision, but few have dealt with the perception of moving colored objects. Are certain colors of moving objects more visually perceptible to the human eye than other colors? If so, sports seem to be one aspect of our lives that could be affected greatly.

Most of the traditional sports in which we engage revolve around the use of a moving object, usually a ball. Colored tennis balls were introduced approximately twenty years ago and have now replaced the white tennis ball in popularity. If colored tennis balls are popular with participants because they are more visually perceptible than white tennis balls, would the same hold true for other sports, particularly baseball? This question and the author's interest and experience in baseball led to this

investigation of the visual perception and hitting effectiveness of yellow, orange, and white baseballs.

STATEMENT OF THE PROBLEM

The purpose of this study was to investigate the visual perception of three colors of baseballs by college baseball batters and to determine whether there are any differences in the batters' effectiveness in hitting one color of baseball versus another color of baseball. The three colors of baseballs used in this study were:

1. High Visibility Yellow
2. High Visibility Orange
3. White.

HYPOTHESES

For the purpose of this study, the following null hypotheses were developed:

1. There will be no significant difference in the rank order preference of the yellow, orange, and white baseballs as determined by the visual perceptions of participating college baseball players.

2. There will be no significant difference in the effectiveness with which college baseball players hit the yellow, orange, and white baseballs.

3. There will be no significant difference in the rank order preference of the yellow, orange, and white

baseballs as determined by the visual perceptions of a randomly selected group of non-baseball playing college male students.

NEED FOR THE STUDY

The results of this study could possibly indicate that the color of the baseball has a significant effect upon the visual perception and hitting effectiveness of college baseball players. Therefore, the possibility exists that a high visibility color of ball could replace the traditional white baseball at all levels of competition. At the younger age levels of competition, where the players' coordination and skill are in the developmental stages, the color of a baseball providing maximum visual perception would seem significant from a safety standpoint. At the higher levels of competition, such as college and professional, a high visibility color of baseball could mean more offense and better defense in the game. Also, a more visually perceptible baseball could possibly make watching a baseball game more meaningful and enjoyable to the spectators, as well as make the difficult task of umpiring a much easier one.

LIMITATIONS OF THE STUDY

1. Subjects selected for this study were limited to the five best hitters, as judged by the team coach, on the

1978 varsity baseball team at David Lipscomb College in Nashville, Tennessee.

2. The entire study was conducted outdoors on a baseball field during the daylight hours in an effort to duplicate actual playing conditions and was dependent upon the weather conditions; therefore, the amount of light could not be controlled.

3. The visual perception of the batters to each of the three colors of baseballs was determined by the subjective opinions of the participants.

4. The number of batters and the number of pitches were limited because of the expense of a high speed movie camera plus the buying and developing of high speed movie film shot at 500 frames per second.

BASIC ASSUMPTIONS

The following assumptions were made in undertaking this study:

1. The college baseball players selected for this study were above average in batting skill for college-level participants.

2. The participants were not biased concerning their visual perception of the yellow, orange, and white baseballs.

DEFINITIONS OF TERMS

For the purpose of this study the following terms will be noted:

Visual perception--the awareness of objects through the sense of sight.[1]

Hue--a particular shade or tint of a color.[2]

High visibility yellow--the fluorescent shade of yellow similar to that used on PENN tennis balls.

High visibility orange--the fluorescent shade of orange similar to that used on PENN tennis balls.

White--the color of the traditional baseball.

Color blindness--"diminished ability to perceive differences in color."[3]

Pseudo-isochromatic plates--"charts with colored dots of various hues and shades indicating numbers, letters, or patterns, used for testing color discrimination."[4]

Hitting effectiveness--the percentage difference in the velocity of the baseball after being hit versus its velocity coming to the batter from the pitcher.

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[1] Webster's New World Dictionary (Nashville: The Southwestern Company, 1963), p. 552.

[2] Ibid., p. 363.

[3] Daniel Vaughan, Robert Cook, and Taylor Asbury, General Ophthalmology (Los Altos, California: Lange Medical Publications, 1965), p. 348.

[4] Ibid., p. 350.

Percentage difference--percentage obtained by subtracting the velocity of the baseball coming in to the batter from the velocity of the ball leaving the bat after being hit, then dividing the remainder by the velocity of the ball coming in to the batter, and multiplying the quotient by 100.

Analysis of variance--statistical procedure for "dividing the variation observed in experimental data into different parts, each part assignable to a known source, cause or factor."[5] In this study, analysis of variance was used to analyze the hitting effectiveness data for the college baseball players.

Friedman two-way analysis of variance by ranks--nonparametric statistical method used to determine whether the visual perception color ranking totals differed significantly.[6]

Sign test--nonparametric statistical procedure that uses plus and minus signs rather than quantitative measures as its data.[7] The sign test was utilized in this study to

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[5]George A. Ferguson, Statistical Analysis in Psychology and Education (2d ed.; New York: McGraw-Hill Book Company, 1966), p. 281.

[6]Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Company, 1956), pp. 166-173.

[7]Ibid., pp. 68-75.

rank with respect to each other the two members of each pair of colors ranked by the students and baseball players according to visual perception.

Chapter 2

REVIEW OF RELATED LITERATURE

The review of literature for this investigation has been categorized into the areas of visual perception, color perception, tennis, and baseball, followed by a summary.

Ball playing has played a major role in the lives of most American males for many years, and its popularity seems to grow year by year. Either as participants or spectators, Americans spend countless hours each year looking at some kind of ball game--baseball, basketball, football, golf, racquetball, ping pong, soccer, volleyball, and/or tennis are examples. It seems that many times someone who is either playing or watching has said, "I can hardly see the ball," or "It's hard to follow the ball," or "I can not see the ball." Is it because so many Americans have such poor eyesight that they can not follow the flight of the ball? Inadequate vision could be part of the problem, but the investigator feels that the color of the ball has a great deal to do with a person's visual perception of the ball in flight, and consequently affects the quality of his performance.

VISUAL PERCEPTION

Morris[1] stated that the ability to perceive three-dimensional objects (e.g., balls) traveling through one's space field is a difficult task. Many factors affect the ability to accurately perceive moving balls, such as the size of the visual space field, the velocity of the ball, the size of the ball, the direction of the ball's flight, the trajectory angle of the ball, light intensity, and the nature of the background. According to Bruce,[2] the sports performer is at the center of a space field which calls for frequent perceptual judgments. The athlete continually bases his actions upon the perception of dynamic qualities in space, such as balls coming toward him to be struck or caught. Whiting[3] indicated that participants using balls must have the ability to judge the position of an object in space in order to visualize spatial relationships. The investigator feels that the use of a high

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[1]G. S. Don Morris, "Effects Ball and Background Color Have Upon the Catching Performance of Elementary School Children," Research Quarterly, LXVII (October, 1976), 409-416.

[2]Russell Bruce, "The Effects of Variations in Ball Trajectory Upon the Catching Performance of Elementary School Children" (unpublished Doctoral dissertation, University of Wisconsin, 1966), p. 24.

[3]H. T. A. Whiting, Acquiring Ball Skill: A Psychological Interpretation (Philadelphia: Lea and Febiger, 1969), pp. 62-71.

visibility color or colors may aid in the visual perception of moving balls, thus enabling the participant to more effectively perform such ball handling skills as striking and catching. Ridenour reported that "research relating to visual perception and ball handling skills such as striking, catching, and kicking is sparse and fragmentary."[4]

COLOR PERCEPTION

As communicated by Billmeyer,[5] there is very little information in the literature dealing with the visual perception of colored objects, whether moving or not, as a function of their color. After much literature searching, Glass[6] found very little information concerning the perception of opaque colored moving targets. He also stated that the majority of research is concerned with perceptions of moving light targets. In one of the few studies found on this topic, Morris[7] reported that white baseball-sized

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[4]Marcella Ridenour, "Influence of Object Size, Speed, and Direction on the Perception of a Moving Object," Research Quarterly, XLV (October, 1974), 294.

[5]Dr. Fred W. Billmeyer, Jr., Secretary, Inter-Society Color Council and Department of Chemistry, Rensselaer Polytechnic Institute, Troy, New York, personal letter, November 28, 1977.

[6]Dr. Robert A. Glass, Research Psychologist, Sensory Environment Program, United States Department of Commerce, National Bureau of Standards, Washington, D.C., personal letter, February 14, 1978.

[7]Morris, pp. 409-416.

plastic balls produced statistically significant lower-catching performance scores than did yellow and blue balls among second, fourth, and sixth grade children. On the other hand, Schoney[8] studied the effects of red, green, and blue tennis balls upon the catching performance of 8.5 to 11.5 year old boys and girls, and concluded that object color did not influence the ability to catch balls.

Although few studies have dealt with moving objects, the literature does contain some interesting information related to color and visual perception. According to Gramza and Witt,[9] Navrat,[10] and Corah,[11] the ability to perceive various colors seems to be a function of illumination type, intensity, background, and age. It appears, however, that age is not a determining factor in the perception of color

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[8]Madeline Hill Schoney, "The Effects of Varying Color and Direction of Projection on the Catching Performance of 8.5 to 11.5 Year Old Boys and Girls" (unpublished Master's thesis, Purdue University, 1973).

[9]Anthony F. Gramza and Peter A. Witt, "Choices of Colored Blocks in the Play of Pre-School Children," Perceptual and Motor Skills, XXIX (December, 1969), 783-787.

[10]Marian L. Navrat, "Color Tint Matching by Children," Perceptual and Motor Skills, XXI (August, 1965), 215-222.

[11]Norman L. Corah, "Color and Form in Children's Perceptual Behavior," Perceptual and Motor Skills, XVIII (February, 1964), 313-316.

after adolescence.[12] Richards[13] concluded that the amount and type of lighting affected the interpretation of colors. Science Digest[14] reported that the amount of light an object reflects and its hue and vividness could make the object appear as much as 13.5 percent larger than another object of exactly the same size. Whittle[15] stated that the perception of color was influenced by the type of background. Gaines[16] discovered that among five and six year old children yellow and orange were the fastest and easiest hues to discriminate. Connors and Kelsey[17] studied the relationship of the color of an object to peripheral vision in youngsters and adults and found that yellow and blue are the most

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[12]K. H. Ruddock, "The Effect of Age Upon Color Vision-II. Changes with Age in Light Transmission of the Ocula Media," Vision Research, V (1963), 47-58.

[13]Oscar Richards, "Lighting an Examination Room to Avoid Error," American Journal of Optometry and Archives of the American Academy of Optometry, L (June, 1973), 452-457.

[14]"White and Red Look Bigger than Black and Green," Science Digest, XXXVIII (November, 1955), 38.

[15]Paul Whittle, "The Brightness of Coloured Flashes on Backgrounds of Various Colours and Luminances," Vision Research, XIII (1972), 621-638.

[16]Rosslyn Gaines, "Variables in Color Perception of Young Children," Journal of Experimental Child Psychology, XIV (October, 1972), 196-218.

[17]M. M. Connors and P. A. Kelsey, "Shape of the Red and Green Color Zone Gradients," Journal of Optometry Society in America, LI (1961), 874-877.

visible colors in the periphery. Mount[18] concluded that object color and background influenced depth perception, an important factor in playing ball. He found that the color of the object which contrasted most with the backgrounds was seen more clearly than those which contrasted to a lesser degree.

Yellow

Most of the research conducted on the visual perception of colors agrees with the conclusion of Scientific American[19] that the most conspicuous and visible of hues is yellow, followed in order by brilliant yellow-green and orange. This publication also disclosed that yellow and yellow-green are the regions of highest visibility in the spectrum. Birren[20] declared that yellow is the "brightest hue in the spectrum, is sharply focused by the eye, and is free of aberration. . . ." Birren[21] also purported that yellow is the color of highest visibility in the spectrum and will be seen as the nearest and largest of

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[18]George Mount, "Distance Judgments of Colored Objects," Journal of General Psychology, LV (1956), 207-214.

[19]"Yellow Often Better than Red," Scientific American, CLXIX (December, 1943), 274.

[20]Faber Birren, Principles of Color (New York: Van Nostrand Reinhold Company, 1969), p. 77.

[21]Faber Birren, Color, Form, and Space (New York: Reinhold Publishing Corporation, 1961), pp. 44, 47, 60.

colors, followed by white. He also reported that in daylight yellow and yellow-green have the highest visibility. According to Clulow,[22] yellow is the brightest color because most yellow materials highly reflect the light of about two-thirds of the spectrum.

Wilson[23] communicated that yellow is considered to have the highest visibility, as evidenced by the yellow fog lights for airport runways, yellow fire lanes, yellow caution signs, yellow taxi cabs and the switch from red to yellow for hunters' caps. Gergel[24] recently wrote that the red fire engine is on its way out and is being replaced by lime yellow for safety's sake.

According to Hill,[25] the Armed Forces have been interested in the visibility of colors for many years. Experience has taught the military that yellow affords high visibility; for this reason they make extensive use of yellow dye and yellow rescue rafts on the high seas. Hill

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[22]Frederick W. Clulow, Color: Its Principles and their Applications (New York: Morgan and Morgan, Inc., 1972), p. 71.

[23]Midge Wilson, Executive Director, The Color Association of the United States, Inc., 200 Madison Avenue, New York, New York, personal letter, November 23, 1977.

[24]Richard Gergel, "Yellow Is In," The Daily News Journal (Murfreesboro, Tennessee), September 29, 1977.

[25]Carson Hill, "The Color that Saves Lives," American Mercury, LXXXVII (November, 1958), 77-80.

related the results of a series of tests on color determination conducted by the United States Army. These tests showed that the color most easily seen and identified proved to be yellow. It was correctly identified four to five times more often than any other color. Even a team of color-blind servicemen had no difficulty seeing yellow.

Orange

Orange is also reported as a high visibility color. Birren[26] stated that, optically, orange produces a sharp image. Bradford[27] investigated the noticeability of colors by giving a reading test to a sample of primary and secondary school students. He concluded that there is a tendency for stimuli pigmented in the orange-red arc of the spectrum to have a high noticeability factor. MacAdam[28] communicated that in order to obtain maximum contrast, which is needed for maximum acuity and perception under any circumstances, an object seen against the sky (whether blue or gray), or against grass, should be orange and as light as possible (e.g., fluorescent).

On August 12, 1975, Al Campanis, Los Angeles Dodgers executive, patented a fluorescent orange catcher's mitt as a

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[26]Birren, Color, Form, and Space, p. 60.

[27]Leslie Bradford, "Noticeability of Colours," Educational Review, XXIV (February, 1972), 93-98.

[28]Dr. David L. MacAdam, Optical Society of America, personal letter, December 5, 1977.

target. The mitt has a two and one-half inch perimeter of orange fluorescent vinyl that outlines the glove and makes it a vivid target for the pitcher, particularly during night games.[29]

White

According to Science Digest,[30] white makes an object look larger than a color would, and some colors will make objects appear larger than other colors will. Women shopping for shoes are usually aware of this effect and will choose a black pair instead of a white pair simply because their feet look smaller in black shoes than in white.

TENNIS

The use of colored balls in sports is a relatively recent innovation. Colored tennis balls, specifically yellow and orange, have been more accepted by the tennis participants than have colored balls in other popular sports. In fact, the yellow and orange tennis balls are being used so extensively now that Starbuck[31] predicted

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[29]Mickey McConnell, "New Dodger Brainstorm Illustrates Value of 'Visualization,'" Collegiate Baseball, XIX (April 23, 1976), 8.

[30]"White and Red Look Bigger than Black and Green," Science Digest, p. 38.

[31]Fred L. Starbuck, Tennis Product Manager, Penn Athletic Products, Jeannette, Pennsylvania, personal letter, September 6, 1977.

the white tennis ball may become extinct in the near future.

A recent article in Consumer Reports[32] declared that the yellow tennis ball is now the rage, probably because yellow tennis balls are easier to see. Some models of tennis balls manufactured today are available only in the yellow color. Weiser[33] disclosed that presently about 90 percent of the market is in yellow balls. Consumers' Research Magazine[34] reported that the yellow balls are believed to be more visible in artificial light. Consumer Reports[35] also stated that some indoor players prefer yellow balls because it is easier to follow their flight against the glare of artificial lighting.

However, test results published in the Penn Tennis Products[36] catalog show the orange tennis ball to be most visible under actual playing conditions: grey (concrete), green (grass), blue (sky), and dark grey (asphalt). Yellow,

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[32]"Tennis Balls," Consumer Reports, XLII (March, 1977), 131-133.

[33]Steven Weiser, Racquet Sports Development Engineer, Dunlop Sports Company, Buffalo, New York, personal letter, September 26, 1977.

[34]"Tennis Balls," Consumers' Research Magazine, LIX (February, 1976), 13-16.

[35]"Tennis Balls," Consumer Reports, XXXVI (July, 1971), 412-414.

[36]Penn Tennis Products, catalog, Penn Athletic Products, Jeannette, Pennsylvania, 1977.

orange, and white tennis balls were tested against the above mentioned backgrounds at medium and high speeds under dim, medium, and bright illumination. Independent observers viewed the samples under these varying conditions and recorded their impressions. See the illustration on page 19 for a summary of test results.

BASEBALL

Since research shows that yellow and orange are high visibility colors, why have not more sports, particularly baseball, begun using balls of these colors? The investigator has found very little in the literature on the subject of colored baseballs, and what exists is equivocal in certain instances. Johnson[37] supported the author when he communicated that, regarding "the use of colored baseballs, there is very little information or data available." However, he said that colored baseballs were experimented with on two occasions, a yellow ball in the late 1940's and the orange ball about two years ago. "They did not seem to generate any interest and support and no in-depth tests were conducted."[38] According to Feeney,[39] there was some

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[37]John H. Johnson, Administrative Officer, Office of the Commissioner of Baseball, New York, personal letter, March 29, 1978.

[38]Ibid.

[39]Charles S. Feeney, President, The National League of Professional Baseball Clubs, New York, personal letter, February 15, 1978.

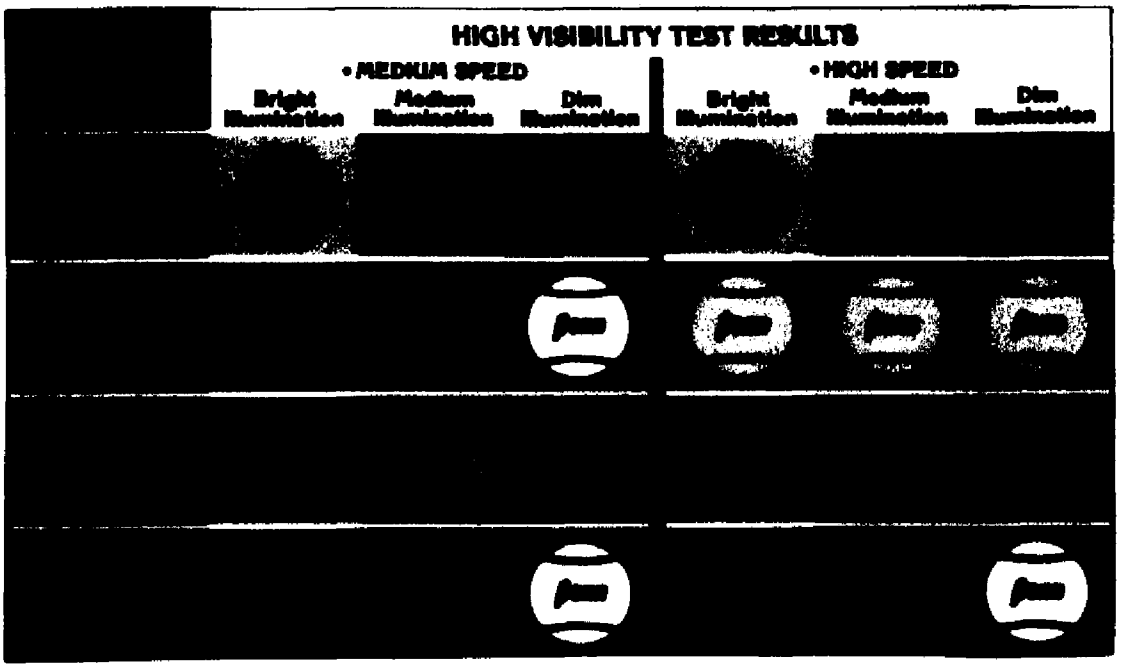

Figure 1. High Visibility Test Results

RESULTS:

Orange balls most visible against light grey background under all conditions.

Orange balls most visible against blue background under all conditions.

Orange balls most visible against dark grey background under most conditions. (White balls easier to see in dim light.)

Orange balls most visible against green background under some conditions (yellow balls most visible at high speed, white balls most visible in dim light at medium speed).

Source: Penn Tennis Products, catalog, Penn Athletic Products, Jeannette, Pennsylvania, 1977.

experimentation with colored baseballs in the late 1930's. Foss[40] wrote that Frederic H. Rahr proposed the yellow baseball over thirty years ago, and it was actually used in the major leagues. Mrs. Rahr[41] confirmed that her late husband proposed a yellow baseball because it was a time of many "bean balls," head injuries, and white shirts in the bleachers. The Brooklyn Dodgers used it and liked it, but opposing clubs did not. Roewe[42] communicated that "we can find very little in our files on the use of colored baseballs in organized ball." He purported that the National League experimented with an orange ball in 1938 and also in 1939. Four league games were played using the colored ball. The president of the National League refused to approve use of the orange ball and there were no further attempts to legalize it until 1964 when Charlie Finley, owner of the Oakland A's professional baseball team, made a futile attempt to gain its acceptance. Redding[43] wrote that "there

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[40]Carl E. Foss, Optical Society of America, personal letter, December 5, 1977.

[41]Julia B. Rahr, Palm Desert, California, personal letter, December 13, 1977.

[42]Chris Roewe, The Sporting News, 1212 N. Lindbergh Blvd., St. Louis, Missouri, personal letter, October 19, 1977.

[43]John Redding, Librarian, National Baseball Hall of Fame and Museum, Inc., Cooperstown, New York, personal letter, November 16, 1977.

is very little material on the subject of colored baseballs." He related that a red ball was tried in the early days and in 1939 the Dodgers experimented with an orange or yellow one. Campanis,[44] however, denied that the Dodgers experimented with an orange baseball in 1939. He believed a game was played using an orange colored baseball in 1939 at New York University. William McCarthy,[45] baseball coach at New York University in 1939, confirmed that a game was played in 1939 using an orange colored baseball, but the contest was between Fordham University and Columbia University. The teams were coached by Jack Coffey and Andy Coakley, respectively; and the game was broadcast by radio station WOR. Time[46] reported in 1964 that Charlie Finley advocated an orange colored baseball and in 1975[47] quoted Finley as saying, "Batters can see an orange ball better, particularly at night. . . ." However, McConnell[48] disclosed that it was Raymond Dumont, founder of the National Baseball Congress, who brain-waved into existence

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[44]Al Campanis, Vice President, Los Angeles Dodgers, Los Angeles, California, personal letter, February 27, 1978.

[45]William V. McCarthy, 1775 Broadway, New York, New York, personal letter, April 13, 1978.

[46]"What Every Team Needs," Time, LXXXIII (January 24, 1964), 30.

[47]"Charlie Finley: Baseball's Barnum," Time, CVI (August 18, 1975), 42-43+.

[48]McConnell, p. 8.

the orange baseball. Davis[49] agreed and added that Mr. Dumont had stocked orange baseballs several years prior to 1959, when they were used in the National Baseball Congress Tournament to stimulate sales. Davis also related that in the mid-60's Dumont innovated a gold Glo-Bal (bright yellow in color) that the players preferred over the orange ball. The cost, however, could very well have been the reason these balls were not adopted. The colored baseballs sold for $26.75 per dozen, while a quality white horsehide-covered ball could be purchased at that time for $16.95 per dozen. Also, more balls were used during a game because fans were reluctant to return them. Watson[50] wrote that in 1973 the Oakland A's and the California Angels played an entire spring exhibition game with an orange colored ball. The A's won, 8-3. Charlie Finley, Oakland A's owner, ordered the experiment because he felt the hitter and the fan could follow the orange colored baseball more easily.

The game of baseball revolves around the act of hitting a baseball, a most difficult task dependent upon visual perception, eye-hand coordination, and split-second

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[49]Larry Davis, Vice President, General Manager, National Baseball Congress, Wichita, Kansas, personal letter, March 16, 1978.

[50]George Watson, "Colored Ball Experiment is Conducted," Collegiate Baseball, XVI (May 18, 1973), 9.

timing. According to Ted Williams,[51] one of baseball's all-time greatest hitters, "hitting a baseball . . . is the single most difficult thing to do in sport." His statement would be difficult to dispute, since Hubbard,[52] Scott,[53] Slater-Hammel and Stumpner,[54] Newell,[55] and Reiff[56] reported that fast balls usually range in speed from 0.58 to 0.43 seconds from the pitcher's mound to home plate. With the baseball traveling 60.5 feet at such high speeds, the batter is faced with the problem of hitting a round ball only nine to nine and one-fourth inches in circumference with a round bat that is two and three-fourths inches or less in diameter at the thickest part.[57] Add to this the unknown path of the baseball and it is evident that hitting a baseball is a most

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[51]Ted Williams and John Underwood, The Science of Hitting (New York: Simon and Schuster, 1971), p. 7.

[52]A. W. Hubbard, rebuttal to comments by Slater-Hammel on "Visual Movements of Batters," Research Quarterly, XXVI (October, 1955), 366-368.

[53]M. Gladys Scott, Analysis of Human Motion (New York: F. S. Crofts and Company, 1945), pp. 144-145.

[54]A. T. Slater-Hammel and R. L. Stumpner, "Batting Reaction-Time," Research Quarterly, XXI (December, 1950), 353-356.

[55]K. M. Newell, "Decision Processes of Baseball Batters," Human Factors, XVI (October, 1974), 520-527.

[56]Guy G. Reiff, What Research Tells the Coach About Baseball (Washington, D.C.: The Division of Men's Athletics of AAHPER, 1971), p. 5.

[57]National Baseball Congress of America, 1977 Official Baseball Rules (Wichita, Kansas: National Baseball Congress of America, 1977), p. 3.

difficult skill. Since the charm of baseball, as stated by Tuckett,[58] is in the action that begins when the ball is hit, why not enhance the possibility of more hitting by using a color of baseball that is more visually perceptible to the hitter? Simpson[59] probably gave the answer when he stated that people connected with baseball have usually been averse to change of any kind.

SUMMARY

The literature suggests the possibility that color may be an influencing factor in the visual perception of three-dimensional objects moving through space. However, very little information is available to substantiate the use of colors on balls used in sports.

To the knowledge of the investigator, no published research has been done on the subject of colored baseballs or colored balls used in other sports. Gavrisky[60] and

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[58]Glenn Tuckett, "Baseball's Charm: Action Generated by a Hit Ball," Collegiate Baseball, XVI (May 18, 1973), 1.

[59]Allan Simpson, "At All-Time Peak, College Game Gets Better and Better," Collegiate Baseball, XXI (January 6, 1978), 4.

[60]Velu Gavrisky, "Vision and Sporting Results," Journal of Sports Medicine and Physical Fitness, X (December, 1970), 260-264.

Ghosh[61] suggested that various colors be used to aid athletes in their performance of any motor activity that requires visual perception. However, no research has been found by this investigator that has determined which color or colors would best facilitate the motor performance of the participants. If the results of this study indicate that the color of the baseball has a significant effect upon the visual perception and hitting effectiveness of college baseball players, it is possible that the game of baseball could experience the kind of color revolution that occurred in tennis years ago.

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[61]Aloke Ghosh, "Ocular Problems in Athletics: Role of Opthalmology in Sports Medicine," Journal of Sports Medicine and Physical Fitness, XIII (June, 1973), 111-117.

Chapter 3

METHODS AND PROCEDURES

Certain methods and procedures were used in order to accomplish the purposes of this study. These included the selection of non-baseball playing college male students and college baseball players, as well as the administrative procedures necessary to conduct this experiment. A pilot study was conducted prior to this experiment to familiarize the investigator with the methods and procedures involved in a study of this nature.

PILOT STUDY

The pilot study was conducted during the fall semester of 1977 at Middle Tennessee State University, using the varsity baseball team as subjects. The pilot study pointed out to the investigator some of the problems involved in such an undertaking and helped to better prepare him for the collection of data for this study.

During the pilot study a Kustom Signals HR-8 radar gun from the Murfreesboro Police Department was used in an effort to determine the velocity of the ball coming from the

pitcher to the batter. Due to the size of the baseball, the radar gun recorded less than 50 percent of the pitched balls. Since it was so difficult to obtain velocity readings on pitched balls whose flight paths were relatively certain, it was obvious that it would not be possible to determine with a radar gun velocities of the balls leaving the bat at so many different angles. So, in an effort to determine the effectiveness with which each baseball was hit by the batter, a panel of three baseball coaches used a chart and scale to evaluate each hit ball. Although the three evaluators were knowledgeable baseball coaches, their judgments frequently differed on how effectively each ball was hit. The investigator felt a more accurate measuring device had to be found, and decided on a 16 mm Fastax WF 30 high speed movie camera to measure both the velocity of the ball coming from the pitcher to the batter and the velocity of the ball leaving the bat, thus eliminating the subjective evaluations.

A Tru-Pitch pitching machine was used to throw the baseballs to the batters on the first two days of the pilot study. The pitching machine was very inconsistent in the location of the pitches and caused an adjustment problem for the batters who had been accustomed to hitting live pitching during the fall practice period. Therefore, on the third day of the study a batting-practice pitcher was used. The investigator found the batting-practice pitcher to be more

consistent in the location of pitches and was unanimously preferred by the batters over the pitching machine.

Immediately after they had finished hitting each day, the batters in the pilot study were asked by the investigator to orally rank the colors of baseballs as to visual perception. These color perception rankings were then recorded for each of the batters. The investigator realized that the batters' hitting performances might influence their perception rankings and determined the batters would probably give more accurate perception rankings prior to hitting the baseballs.

The order in which the colors of balls were thrown was randomly selected beforehand. The batter did not know which color of baseball would be thrown until it left the pitching machine or pitcher's hand. The investigator felt a more accurate measurement of hitting effectiveness could be obtained if the batter hit each color consecutively and, therefore, was not concerned with which color he would see next.

In the pilot study a total of fifteen batters hit fifteen pitches each day, five pitches of each of the three colors of baseballs. For the purpose of this study, the investigator decided that more accurate results could be obtained by decreasing the number of batters and increasing the number of pitches to each batter.

Historically, pilot studies have served useful purposes in allowing the investigator(s) to work out various unknown problems. This pilot study was no exception.

SAMPLE AND CONSTITUTION OF TREATMENT GROUPS

Students

Fifteen non-baseball playing male students at Middle Tennessee State University were selected to act as a control group in this experiment. The fifteen students were chosen from a randomly selected group of 73 males who filled out a sports participation form indicating each one's amount of experience and frequency of participation in baseball, softball, and tennis. The investigator then selected the fifteen people with the least amount of exposure to these three sports who were willing to participate in the experiment. The sports participation form appears in Appendix A.

Baseball Players

The college baseball playing subjects for this study included the five best hitters, as chosen by the head baseball coach, on the 1978 varsity baseball squad at David Lipscomb College in Nashville, Tennessee. David Lipscomb was the 1977 National Association of Intercollegiate Athletics national champion and finished fourth in the national tournament in 1978 with a 50-11 won-lost record.

ADMINISTRATIVE PROCEDURES

Students' Observations

The same procedures were followed on each of the three days in which the test was administered to the control group of fifteen non-baseball playing male college students. The experiment was conducted on three days because of the number of pitches the pitcher would have to throw to the batters. Also, the investigator felt that conducting the experiment on three days would result in a variance in the amount of light present for each testing day. Five different students were tested on each of the three days on the Middle Tennessee State University baseball field. The five participants assembled with the investigator in the area of third base on the baseball field. The author explained to the students the nature of the study and the procedures to follow during the experiment. The instructions given to the students and a diagram of the observation stations appear in Appendix B. In order to avoid one person's influencing another's opinion of the color preference of the baseballs, the participants were instructed not to talk to each other about the baseballs during the experiment. Each participant then drew a number from one to five to determine the order of participation.

Each student then proceeded in order to the third base dugout and was given a color blindness test using the

pseudo-isochromatic plates from the American Optical Company. The color blindness test form used by the investigator appears in Appendix C. These charts are composed of patterns (numbers, letters, etc.) made up of variously shaded dots of the primary colors set on a differently colored background of similar dots in confusion color. The color tints used were selected with the aid of a color-blind painter so as to correspond to the confusion colors of one who is color-blind. The dots vary in intensity so that the individual can not depend on his perception of light intensity to aid him in reading the figure. He must rely solely on his color perception. Composed of the primary colors, the figures are readily seen by a normal person. The color-blind person, however, can not recognize the differences in color and is unable to distinguish the figures from the background or, in mild degrees of color blindness, shows hesitancy in naming them. Plates are provided for the detection of each type of color blindness. The type and degree of color blindness are determined by the plates missed or read with hesitation.[1]

After all five students had passed the color blindness test, a curtain was placed in front of the dugout so that the participants could not see the area between the

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[1]Joshua Zuckerman, Diagnostic Examination of the Eye (2d ed.; Philadelphia: J. B. Lippincott Company, 1964), pp. 262-264.

pitcher's mound and home plate. Following the original order of participation, each student took his respective turn in the batter's box to look, but not to swing, at thirty pitched baseballs including ten pitches of each of the three colors of baseballs. All pitches were thrown by an experienced college batting-practice pitcher at approximately the same speed. The order in which the three colors of baseballs were thrown to each participant was randomly selected beforehand. The amount of light present at each pitch was recorded in footcandles from a Kahlsico light meter. After looking at thirty pitches, each student then proceeded to the first base dugout. There he ranked the yellow, orange, and white baseballs from the most perceptible to the least perceptible to him. The participant's rankings were recorded and he was then requested to leave the ball park.

Baseball Players' Observations

The same procedure was used in administering the observation portion of this experiment to the five college baseball players from David Lipscomb College as was used with the non-players. See Appendix B for the observation procedure. The location of the experiment was the baseball field on the campus of David Lipscomb College in Nashville, Tennessee. A regular batting-practice pitcher from the David Lipscomb College baseball team served as pitcher for

the players' observation test. This same individual also served as batting-practice pitcher for the hitting portion of the experiment. After the players had passed the color blindness test and ranked the colors as to visual perception, days and times were scheduled to conduct the three trials of hitting the three colors of baseballs.

Baseball Players' Hitting

The experiment was conducted at the home baseball field of David Lipscomb College so that each participant was in familiar surroundings. It was also felt that as a result each participant would be more at ease and less nervous about being tested than if he were brought to unfamiliar surroundings. Each of the five baseball players was given three trials on separate days to swing at ten pitches of each color of baseball during each trial.

Before the participants arrived, all the equipment used in the experiment was set up on the baseball field. The baseball field was marked off by cones into twenty-four equal sections, each a fifteen degree angle from home plate. The location of each ball hit by the batter was marked on a hitter's chart according to the section of the field in which it landed. The complete hitter's chart and an enlarged sample appear in Appendix D. The 16 mm Fastax WF 30 high speed movie camera used to film each pitch was positioned at a right angle to home plate, facing the batter

on the opposite side of home plate. See Appendix E for the position of the camera. A Kahlsico light meter, which measured the amount of light in footcandles, was positioned directly behind home plate on the opposite side of the backstop screen. The amount of light present during each hit and the location of each batted ball were recorded on a hitter's chart from this vantage point. The hitter's chart can be found in Appendix D. Three buckets, each containing ten baseballs of one of the three colors used in this experiment, were placed behind the pitcher's mound. Extra balls of each color were on hand in case any balls were damaged or lost.

The nature of the study and the procedures to follow during the experiment were explained to the participants prior to testing. The instructions given to the batters and a diagram of the test format appear in Appendix E. In order to avoid one player's influencing another player's opinion of the color preference of the baseballs, the participants were instructed not to talk to each other about the baseballs during the experiment.

Following the explanation of the study, each player drew a number from one to five to determine the random order in which each would take his turn hitting the baseballs. While the participant who was to bat first was loosening up, the other four players were stationed behind the dugout so they could not see the balls being thrown and hit. Prior to

his turn at bat, each participant was instructed to go through the warm-up exercises he normally takes before batting practice during the regular college baseball season. Since the team had no specific set of exercises for the players to follow, each participant was allowed to warm-up in his own individual manner.

Upon completion of his warm-up exercises, each participant took his respective turn in the batter's box to swing at ten successive pitches of each color of baseball thrown by the batting-practice pitcher. Each pitch at which the batter swung was counted in this study, whether it was hit or missed. Each batter swung at ten pitches of each color before swinging at the next color of baseball. A regular batting-practice pitcher from the David Lipscomb team served as batting-practice pitcher for this experiment in an effort to alleviate the variable of the batters having to adjust to an unfamiliar pitcher. A batting-practice pitcher was used instead of a pitching machine because Bryant et al.[2] conducted a pilot study to determine the best method of standardizing pitched-ball velocity and found batting-practice pitchers to be more consistent than pitching machines. Also, the pilot study conducted by this investigator showed a batting-practice pitcher to be more

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[2]Fred O. Bryant, Lee N. Burkett, Stanley S. Chen, Gary S. Krahenbuhl, and Ping Lu, "Dynamic and Performance Characteristics of Baseball Bats," Research Quarterly, XLVIII (October, 1977), 505-509.

dependable and preferred by the batters over the pitching machine. See Pilot Study section for further explanation.

The order in which the yellow, orange, and white baseballs were thrown was randomly selected beforehand by the investigator. The experiment's order of pitches was arranged so that each batter would hit each of the colors first, second, and third in the order. One of the following sequences of pitches was randomly selected each day for each hitter: (1) yellow, white, orange; (2) white, orange, yellow: or (3) orange, yellow, white. Each pitch was filmed with a 16 mm Fastax WF 30 high speed movie camera with the speed set at 500 frames per second. The film speed of 500 frames per second was selected because it was the minimum speed setting on the camera and was also fast enough to eliminate blurring of the baseball in the picture.

It was the intention of the investigator to determine from this high speed film the velocity of the pitch coming to the batter and the velocity at which the ball left the bat after being hit. The effectiveness with which each batter hit each pitch thrown to him would then be determined by comparing the velocity at which the ball came in to the batter against the velocity at which the ball left the bat. However, due to inconsistency in the speed in which the film went through the camera, a number of the ball velocity recordings were inaccurate. Therefore, a percentage difference of the ball velocity off the bat

versus ball velocity to the bat was used to determine hitting effectiveness.

This investigation was conducted during the latter part of the 1978 college baseball season.

STATISTICAL PROCEDURES

The data collected in this investigation were analyzed at the .05 level of significance by the following statistical procedures: analysis of variance,[3] Friedman two-way analysis of variance by ranks,[4] and the sign test.[5]

A treatments-by-treatments-by-subjects analysis of variance[6] was used to analyze the hitting effectiveness data for five college baseball players hitting yellow, orange, and white baseballs. This same statistical procedure was also used to analyze the amount of light present for each batter, each color, and each trial. The data were analyzed by computer using the A x B x S ANOVA (ABSAN) program at the Middle Tennessee State University computer center.

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[3]George A. Ferguson, Statistical Analysis in Psychology and Education (2d ed.; New York: McGraw-Hill Book Company, 1966), pp. 281-325.

[4]Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Company, (New York: McGraw-Hill Book Company, 1956), pp. 166-173.

[5]Ibid., pp. 68-75.

[6]E. F. Lindquist, Design and Analysis Experiments in Psychology and Education (Boston: Houghton Mifflin Company, 1953), pp. 237-238.

The visual perception rankings of the students and the baseball players were analyzed by the nonparametric statistical procedure, Friedman two-way analysis of variance by ranks. This statistical method was used to determine whether the visual perception color ranking totals differed significantly.

The sign test was used in the analysis of the visual perception rankings of the students and baseball players by comparing the three colors of baseballs in the following manner: (1) yellow versus white, (2) yellow versus orange, and (3) orange versus white. The sign test is a non-parametric statistical procedure that uses plus and minus signs rather than quantitative measures as its data.

Chapter 4

ANALYSES OF DATA

The data collected and analyzed for this study are presented and discussed in this chapter. Tables of data are also presented and interpreted. The analyses of data are presented in the following order: students' observation results, baseball players' observation results, and baseball players' hitting effectiveness results.

STUDENTS' OBSERVATION RESULTS

The visual perception data on the fifteen non-baseball playing male university students were collected on three days with five different students tested each day. The order in which the students observed the yellow, orange, and white baseballs, their visual perception rankings, and the amount of light present are shown in Appendix F.

The light conditions varied for the three days of testing. On the first day there was a clear sky and bright sun as evidenced by the mean light meter recording of 4880 footcandles of light. The orange baseball was selected by three of the five students as the most visually perceptible color.

The second day of testing was cloudy with no direct sunlight. The mean light meter reading was 640 footcandles of light. Three of the five students ranked the yellow ball first and the other two students chose the orange ball as the most visually perceptible.

The third testing day was also cloudy, but the mean light meter reading increased to 1060 footcandles. On this day the orange baseball was ranked first by three of the five students and the yellow ball received the other two first place visual perception rankings. The students' visual perception rankings and the mean light meter readings for each testing day are found in Table 1.

The order in which the yellow, orange, and white baseballs were thrown to each participant was randomly selected beforehand by the investigator. However, the color sequence of pitches was prearranged so that each of the three colors of baseballs would be thrown first, second, and third the same number of times. Table 2 reveals that each color was observed first in the pitching order five times, second five times, and third five times for the fifteen subjects.

Table 1

Students' Visual Perception Rankings and Mean Light Meter Readings by Days

Day 1

	1st	2nd	3rd
Yellow	1	3	1
Orange	3	0	2
White	1	2	2

4880
Mean Light Meter Reading (in Footcandles)

Day 2

	1st	2nd	3rd
Yellow	3	1	1
Orange	2	2	1
White	0	2	3

640
Mean Light Meter Reading (in Footcandles)

Day 3

	1st	2nd	3rd
Yellow	2	2	1
Orange	3	1	1
White	0	2	3

1060
Mean Light Meter Reading (in Footcandles)

Table 2

Students' Order of Pitches--Totals

Color	1st	2nd	3rd
Yellow	5	5	5
Orange	5	5	5
White	5	5	5

One can readily see from Table 3 that the orange and yellow baseballs were selected by the students as the most visually perceptible colors. Eight of the students ranked orange first, six chose yellow first, and only one of fifteen students selected white as the most visually perceptible color.

Table 3

Students' Visual Perception Rankings--Totals

Color	1st	2nd	3rd
Yellow	6	6	3
Orange	8	3	4
White	1	6	8

The nonparametric statistical procedure Friedman two-way analysis of variance by ranks was chosen to determine whether the fifteen students' visual perception rankings differed significantly. As shown in Table 4, the

results of $X_r^2 = 4.93$ with a critical value = 5.99 indicated that there was statistically no significant difference in the students' visual perception rankings of the yellow, orange, and white baseballs. However, the students' perception rankings in Table 3 seem to indicate a preference for the yellow and orange baseballs over the white ball.

Table 4

Friedman Two-way Analysis of Variance by Ranks for Students' Visual Perception Rankings

Subjects	Ranking Totals Yellow	Orange	White	X_r^2	Critical Value
15	33	34	23	4.93	5.99

The sign test was used to compare the three colors with each other in the following pairs: (1) yellow versus white, (2) yellow versus orange, and (3) orange versus white. The results for the three above mentioned color comparisons at the .05 level of significance were as follow: (1) p = .059 for yellow versus white, (2) p = .500 for yellow versus orange, and (3) p = .059 for orange versus white. The students' sign test results can be found in Table 5. Although p = .059 at the .05 level of significance was barely non-significant statistically for the yellow versus white and the orange versus white baseballs, for

practical purposes there was a significant preference for the yellow and orange baseballs over the white balls.

Table 5

Sign Test for Students' Visual Perception Rankings

Subjects	Color Pairs	Color Preference		p	p*
15	Yellow vs. White	Y = 11,	W = 4	.059	.050
15	Orange vs. White	O = 11,	W = 4	.059	.050
15	Yellow vs. Orange	Y = 7,	O = 8	.500	.050

*Significant at p = .05 level

BASEBALL PLAYERS' OBSERVATION RESULTS

The visual perception data on the five college baseball players were collected on one testing day. The order in which the baseball players observed the yellow, orange, and white baseballs, their visual perception rankings, and the amount of light present are shown in Appendix G.

The order in which the yellow, orange, and white baseballs were thrown to each baseball player was randomly selected beforehand by the investigator. Table 6 gives the random color order for the five players.

The day of the testing was a bright, sunny day in which the mean light meter reading was 3520 footcandles of

Table 6

Baseball Players' Order of Pitches--Totals

Color	1st	2nd	3rd
Yellow	2	1	2
Orange	2	2	1
White	1	2	2

light. As shown in Table 7, three of the five baseball players chose the yellow baseball and two chose the white ball as the most visually perceptible color. None of the five players selected orange as the most visually perceptible color.

Table 7

Baseball Players' Visual Perception Rankings--Totals

	1st	2nd	3rd
Yellow	3	0	2
Orange	0	3	2
White	2	2	1

3520
Mean Light Meter Reading (in Footcandles)

The Friedman two-way analysis of variance by ranks, a nonparametric statistical procedure, was chosen to determine whether the five baseball players' visual perception rankings differed significantly. The results, as

shown in Table 8, of $X_r^2 = 1.2$ with $p = .691$ indicate that there was statistically no significant difference in the baseball players' visual perception rankings of the yellow, orange, and white baseballs.

Table 8

Friedman Two-way Analysis of Variance by Ranks for Baseball Players' Visual Perception Rankings

Subjects	Ranking Totals			X_r^2	Critical Value
	Yellow	Orange	White		
5	11	8	11	1.2	.691

The sign test was utilized to compare the three colors with each other in the following pairs: (1) yellow versus white, (2) yellow versus orange, and (3) orange versus white. The results for the three above mentioned color comparisons at the .05 level of significance were as follow: (1) $p = .500$ for yellow versus white, (2) $p = .500$ for yellow versus orange, and (3) $p = .188$ for orange versus white. The results, found in Table 9, show no statistical significance in the baseball players' visual perception rankings of the yellow, orange, and white baseballs. A greater number of subjects tested would possibly have given more accurate results.

Table 9

Sign Test for Baseball Players' Visual Perception Rankings

Subjects	Color Pairs	Color Preference		p	p*
5	Yellow vs. White	Y = 3,	W = 2	.500	.050
5	Orange vs. White	O = 1,	W = 4	.188	.050
5	Yellow vs. Orange	Y = 3,	O = 2	.500	.050

*Significant at p = .05 level

BASEBALL PLAYERS' HITTING RESULTS

Hitting effectiveness data were obtained from the 16 mm high speed movie film using a Lafayette Motion Analyzer with a Graf/Pen sonic digitizer, serialized with a SAC DC-6 Parallel-to-Serial Converter, and sent to an IBM 370-165-II to be processed. Velocity values were generated, taking into account the angle adjustment for the batted ball, using finite difference methods. More sophisticated smoothing procedures were eliminated due to the limitation of the number of hitting effectiveness values per subject. Hitting effectiveness was determined by the percentage difference in the velocity of the baseball after being hit versus its velocity coming to the batter from the pitcher. The percentage difference was calculated by subtracting the velocity of the baseball coming in to the batter from the velocity of the ball leaving the bat after being hit, then

dividing the remainder by the velocity of the ball coming in to the batter, and multiplying the quotient by 100.[1]

The hitting effectiveness data on the five college baseball players were collected from the three trials of each player hitting the yellow, orange, and white baseballs. The players took a total of 150 swings at each color and missed only three pitches, two white baseballs and one orange ball. Hitting effectiveness measures were obtained from film analysis for 95 percent (142 of 150) of the yellow baseballs, 87 percent (131 of 150) for the orange balls, and 87 percent (130 of 150) for the white balls, a cumulative total of 90 percent (403 of 450) of the baseball players' swings. Appendix H contains the raw data for each player and each trial. The raw data include each pitch, its color, amount of light present, angle of the ball off the bat, and hitting effectiveness as a percentage difference score. A summary of the percentage difference scores for the five baseball players is located in Appendix I.

The statistical procedure analysis of variance at the .05 level of significance revealed no significant difference in the effectiveness with which the five college baseball players hit the yellow, orange, and white baseballs. Table 10 shows the treatments-by-treatments-by-subjects

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[1]Dr. Ralph Mann, Department of Health, Physical Education, and Recreation, University of Kentucky, Lexington, Kentucky, personal letter, June 8, 1978.

analysis of variance for the hitting effectiveness of the players.

A treatments-by-treatments-by-subjects analysis of variance was also used in the analyses of light conditions present for the hitting trials. The statistical results indicate no significant difference at the .05 level, as shown in Table 11.

Table 10

Analysis of Variance for the Baseball Players' Hitting Effectiveness

Variable	df	Sums of Squares	Mean Squares	F Ratios	Critical Values of F*
Subjects	4	1404.60742188	351.15185547	0.	
Colors	2	380.59265137	190.29632568	1.7510	4.46
Trials	2	8.24938965	4.12469482	0.1658	4.46
Colors x Trials	4	190.78259278	47.69564819	0.5303	3.01
Colors x Subjects	8	869.41345215	108.67668152	0.	
Trials x Subjects	8	199.05017090	24.88127137	0.	
Colors x Trials x Subjects	16	1438.44970703	89.90310670	0.	
Total Sum of Squares	44	4491.14538574	102.07148647	0.	

*Significant at p = .05 level

Table 11

Analysis of Variance for the Amount of Light in Footcandles

Variable	df	Sums of Squares	Mean Squares	F Ratios	Critical Values of F*
Subjects	4	2637393.500	659348.37500000	0.	
Colors	2	15344.250	7672.12500000	0.6244	4.46
Trials	2	3387343.000	1693671.50000000	1.2906	4.46
Colors x Trials	4	11527.250	2881.81250000	0.2895	3.01
Colors x Subjects	8	98303.500	12287.93750000	0.	
Trials x Subjects	8	10498169.750	1312271.21875000	0.	
Colors x Trials x Subjects	16	159268.500	9954.28125000	0.	
Total Sum of Squares	44	16807349.750	381985.22265625	0.	

*Significant at p = .05 level

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

This study attempted to determine the effects of yellow, orange, and white baseballs upon the visual perception and hitting effectiveness of college baseball players. Five college baseball players from David Lipscomb College and fifteen non-baseball playing students from Middle Tennessee State University were the subjects for this investigation.

Data were collected on the subjects between March 31 and May 14, 1978. Before being allowed to participate in this study, each of the subjects was given a color blindness test and was found to possess normal color perception. The fifteen non-baseball playing students and the five college baseball players watched ten pitches each of the yellow, orange, and white baseballs, and ranked them from the most perceptible to the least perceptible color to them. Each of the five players also swung at a total of ninety pitches, thirty each of the three colors of baseballs, over a period of three trials. Each batter's swing at the baseballs was

filmed with a 16 mm high speed movie camera. From this film the effectiveness with which each ball was hit was determined by calculating a percentage difference of the velocity of the ball coming to the batter from the pitcher and the velocity of the ball leaving the bat after being hit.

The statistical procedure analysis of variance was utilized in the analyses of data for the hitting effectiveness of the batters. This method was used to determine if there were a significant difference in the effectiveness with which the baseball players hit the yellow, orange, and white baseballs.

The visual perception rankings of the students and the baseball players were analyzed by two nonparametric statistical procedures, the Friedman two-way analysis of variance by ranks and the sign test.

CONCLUSIONS

Based upon the findings reported in the analyses of data, the following conclusions were made concerning the null hypotheses that were tested at the .05 level of significance:

Hypothesis 1. There will be no significant difference in the rank order preference of the yellow, orange, and white baseballs as determined by the visual

perceptions of participating college baseball players--accepted.

Hypothesis 2. There will be no significant difference in the effectiveness with which college baseball players hit the yellow, orange, and white baseballs--accepted.

Hypothesis 3. There will be no significant difference in the rank order preference of the yellow, orange, and white baseballs as determined by the visual perceptions of a randomly selected group of non-baseball playing college male students--accepted.

Although the students' visual perception rankings of the yellow, orange, and white baseballs were statistically non-significant, there seemed to be a trend in the direction of a preference for the yellow and orange balls over the white ball. The yellow and orange baseballs were about equal in the rank order preference of the students, and both of these colors were preferred over the white baseball.

RECOMMENDATIONS

Following are several recommendations that seem appropriate after conducting this study:

1. In further research on this topic, a greater number of batters and pitches to each batter should be utilized. However, such an increase in the number of batters and pitches would require considerable time and

expense for future investigators. Some expense could be saved by filming at a slower frame speed, such as 400 frames per second or possibly even slower. It is of utmost importance that future investigators make certain they use a high quality camera. It would also be wise to employ an experienced high speed photographer.

2. If the necessary equipment is available, it is recommended that this study be conducted using batters with varying levels of hitting skill at different age levels. Different types of pitches, such as curve balls, sliders, etc., could be used, as well as experimenting with other colors of baseballs and different backgrounds. Studies could also be done with other colors of baseballs with color contrasting seams, or even baseballs of two or more colors.

3. Although batting is a central part of the game of baseball, it seems warranted that studies be conducted on the effects of different colored baseballs upon other aspects of the game, such as the fielders, umpires, and even spectators.

4. Since so many baseball games at all levels of competition are played at night, it seems imperative that this study should also be conducted in the daylight under varying light conditions, and at different times of day, especially during the late afternoon hours when in a two hour period the amount of light present changes rapidly under normal conditions.

Because white baseballs have been used for so many years, players would probably be accustomed to seeing only that particular color of baseball. Therefore, the introduction of a different color could possibly require a period of exposure for the players to become accustomed to seeing the new color. Therefore, it is recommended that the yellow and orange baseballs be tested in league play over the period of one or more seasons.

APPENDIXES

APPENDIX A

SPORTS PARTICIPATION FORM

SPORTS PARTICIPATION FORM

Name _____ Age _____

Classification _____ Phone No. _____

Please check the following levels on which you have participated in baseball and softball:

Baseball:

____ College
____ High School
____ Junior High School
____ American Legion
____ Babe Ruth League
____ Little League
____ No Experience
____ Other (please specify)

Softball:

____ Church League
____ Industrial League
____ No Experience
____ Other (please specify)

When was the last time you participated in any of the above leagues?_____

Do you play tennis? ____ Yes ____ No

If Yes, how often?

____ Often ____ Occasionally ____ Seldom

Would you be willing to take part in a doctoral dissertation experiment, if needed?

____ Yes ____ No

APPENDIX B

INSTRUCTIONS FOR OBSERVATIONS

AND

OBSERVATION STATIONS

INSTRUCTIONS FOR OBSERVATIONS

My name is Danny Davis. I am a Doctor of Arts candidate in physical education at Middle Tennessee State University. As part of the requirements for the degree, each candidate is required to write a dissertation. For my dissertation I have chosen to study the effects of yellow, orange, and white baseballs upon the visual perception and hitting effectiveness of college baseball players. To my knowledge there has been no scientific research done in this particular area, so you will be taking part in probably the first scientific study attempted on this subject. The results of the study could possibly have a far-reaching impact upon the game of baseball, and you have the opportunity to play a part in them. Please take this experiment seriously, cooperate fully, and be completely honest in your evaluations.

As you participate in this study, please follow these directions:

1. Each of you will draw a number from one to five to determine the order of participation.

2. When instructed, go to the nearest end of the third base dugout. There you will be given a color blindness test.

3. When this is completed, you will be instructed to proceed to the opposite end of the dugout and remain until otherwise directed.

4. When called, go to the batter's box at home plate. There you will observe thirty baseballs thrown across home plate by a competent college batting-practice pitcher. Ten of these baseballs will be yellow, ten will be orange, and ten will be white, with all ten pitches of one color being thrown in succession before changing to another color. The order in which you will see the three colors of baseballs has been randomly selected beforehand. As you watch each pitch, please concentrate on how visually perceptible each color of baseball is to you.

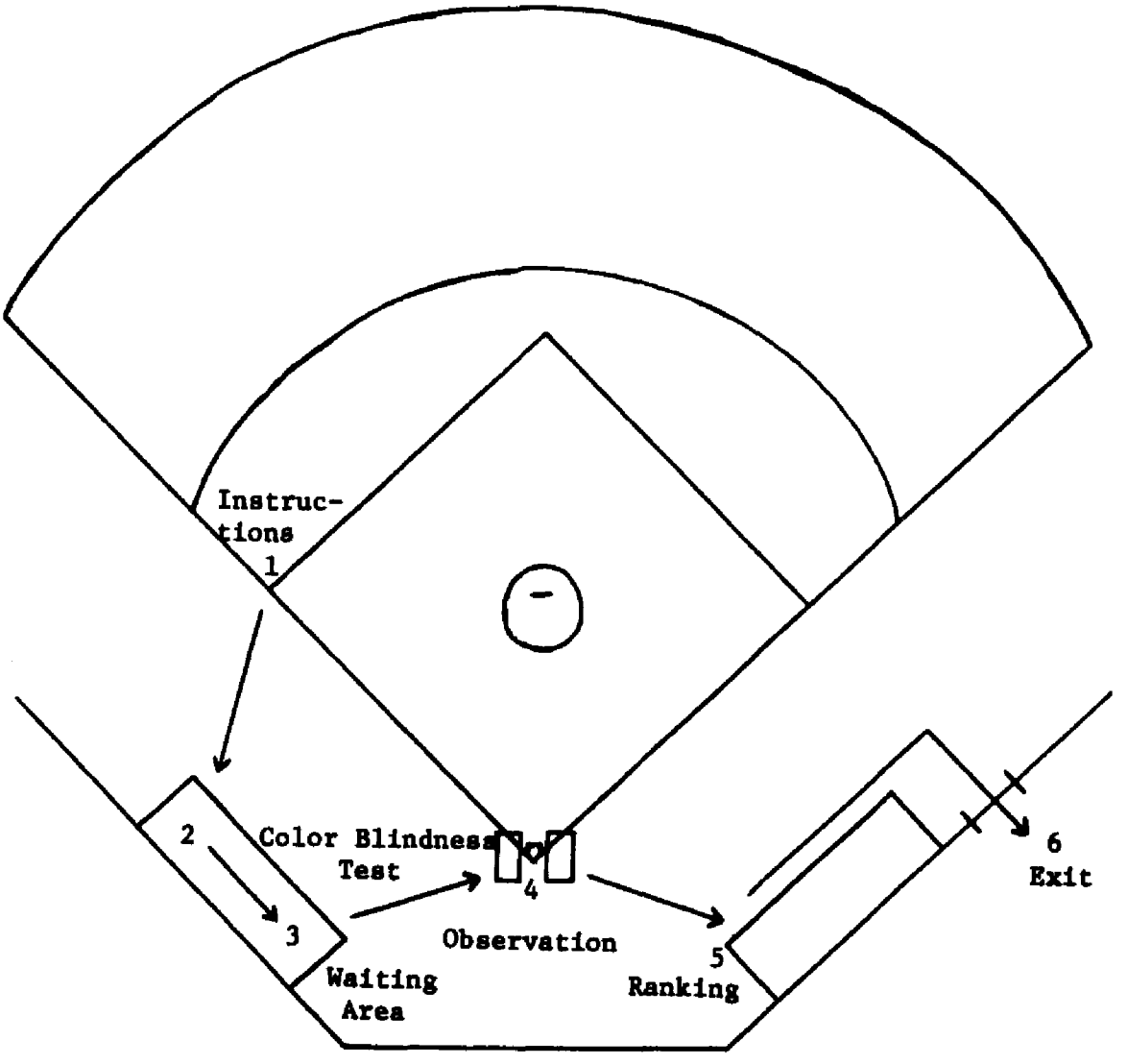
5. After you have observed the three colors of pitched baseballs, go to the first base dugout and rank the three colors from the most perceptible to the least perceptible to you.

6. Then proceed to the gate beyond the other end of the first base dugout and exit from the field.

It is important that each of you understands the procedure to be used in this experiment. Do you have any questions?

Thank you for your participation and cooperation.

OBSERVATION STATIONS



APPENDIX C

TEST FORM: PSEUDO-ISOCHROMATIC PLATES FOR TESTING COLOR PERCEPTION

TEST FORM:

PSEUDO-ISOCHROMATIC PLATES FOR

TESTING COLOR PERCEPTION

Number: _____ Name: _____

Date: _____ Results: _____

Plate Number	Response	Normal Person Reads	Red-Green Blind Reads
1	____	89	Rarely
2	____	43	Rarely
3	____	56	Rarely
4	____	27	Rarely
5	____	8	3
6	____	6	5
7	____	39	Rarely
8	____	42	Rarely
9	____	56	Rarely
10	____	27	Rarely
11	____	29	70
12	____	57	35
13	____	86	Rarely
14	____	75	Rarely
15	____	7	Rarely
16	____	9	Rarely
17	____	25	Rarely
18	____	68	Rarely
19	____	5	2
20	____	3	5
21	____	97	Rarely
22	____	34	Rarely
23	____	56	Rarely
24	____	27	Rarely
25	____	12	12
26	____	H	H

Source: American Optical Company, Pseudo-Isochromatic Plates for Testing Color Perception ([n.p.]: Beck Engraving Company, Inc., 1940).

APPENDIX D

HITTER'S CHART

AND

HITTER'S CHART SAMPLE

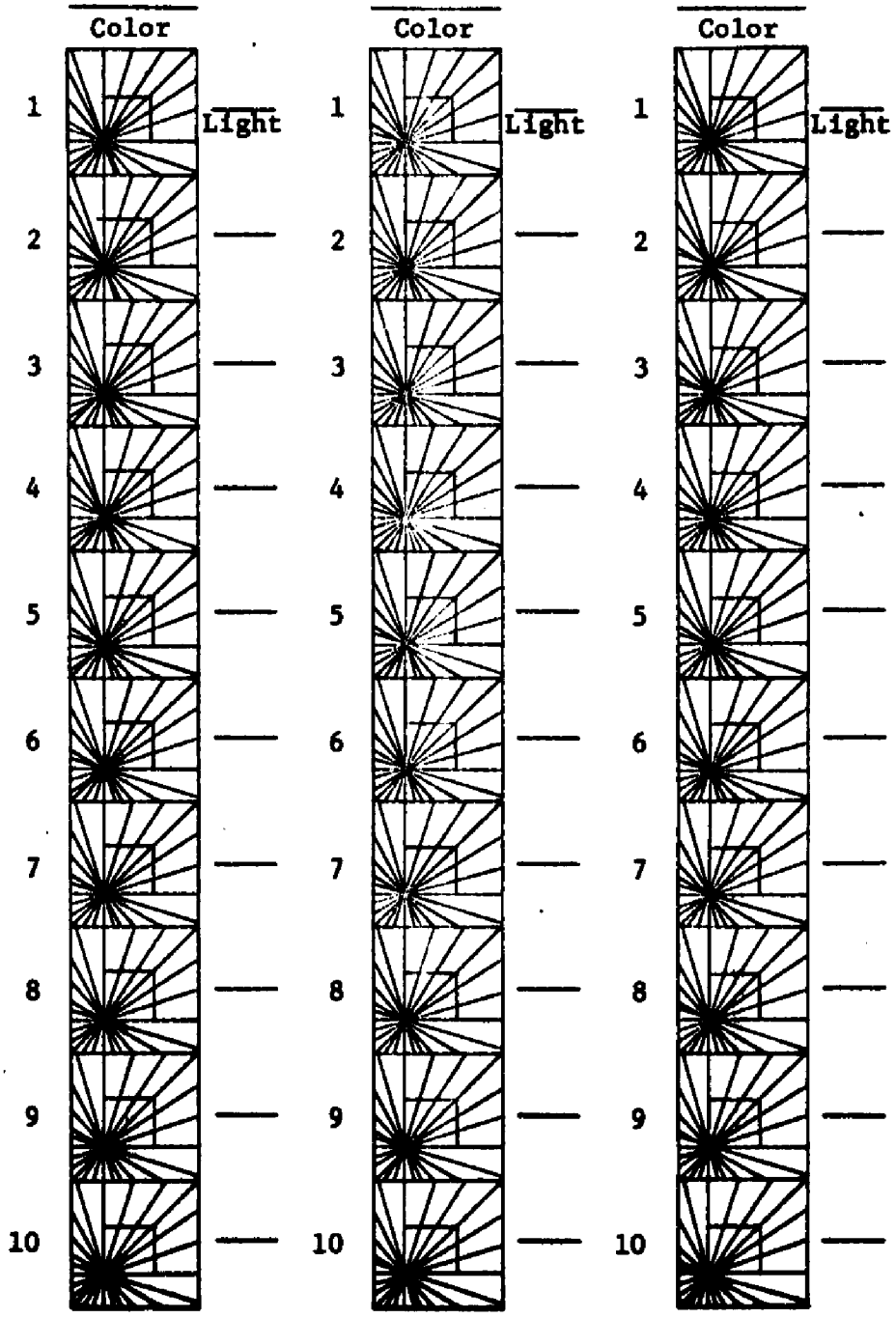
HITTER'S CHART

Name:_____ Right or Left-Handed Batter:_____

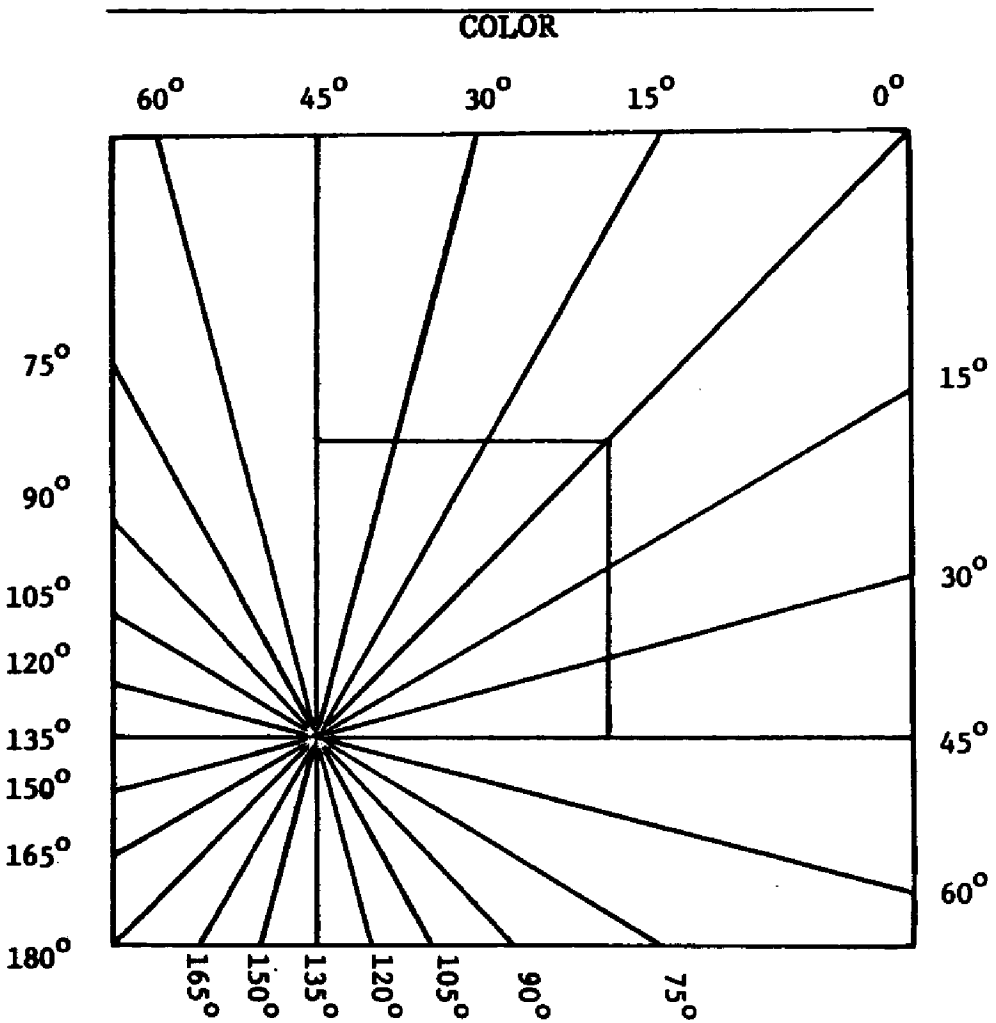
Age:____ Ht.____ Wt.____ Date:_____ Time:_____

Classification:_____ Location:_____

Type of Day:_____ Light in Footcandles:_____



HITTER'S CHART SAMPLE



Number of Swing

Light in Footcandles

APPENDIX E

INSTRUCTIONS FOR HITTING

AND

HITTING STATIONS

INSTRUCTIONS FOR HITTING

As you participate in this study, please follow these directions:

1. Each of you will draw a number from one to five to determine the order of participation for today's testing.

2. Those who drew numbers two through five will go behind the third base dugout and wait until your turn to hit. Please stay behind the dugout so that you will not see the balls being thrown and hit until it is your turn. Before you hit, go through the warm-up exercise routine that you normally follow before taking batting practice during the David Lipscomb College baseball season. You may do your exercises at your station behind the third base dugout while the previous batter is hitting so that we can conserve time.

3. When instructed, go to the batter's box at home plate. There you will be thrown thirty baseballs to hit by a competent college batting-practice pitcher. Ten of the baseballs will be yellow, ten will be orange, and ten will be white, with all ten pitches of one color being thrown in succession before changing to another color. The order in which you will see the three colors of baseballs has been randomly selected beforehand. Please swing at all pitches in the strike zone and all those at which you normally swing in batting practice. You will get ten swings at each color of baseball before another color is introduced. You may use

the bat of your choice, but please use the same bat throughout this experiment.

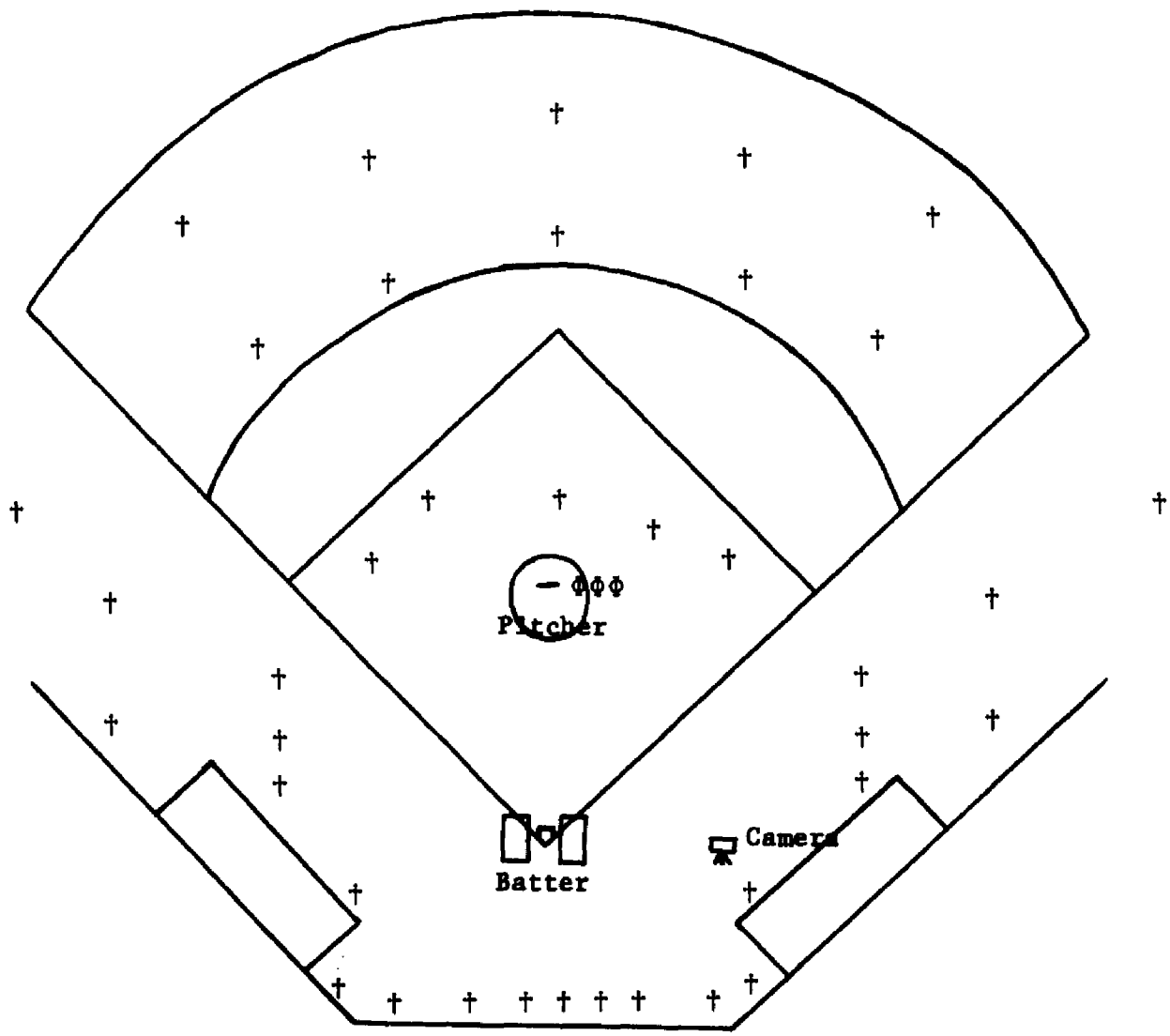
4. After you have taken ten swings at each of the three colors of pitched baseballs, proceed to the gate beyond the first base dugout and exit from the field.

It is important that each of you understands the procedure to be used in this experiment. Do you have any questions?

Thank you for your participation and cooperation.

HITTING STATIONS

(for right-handed batters)*



Light Meter
and
Hitting Chart

*For left-handed batter camera is positioned on third base side of field.

Legend:

† = Cone
ϕ = Ball Bucket

APPENDIX F

RAW DATA FOR STUDENTS' OBSERVATIONS

RAW DATA FOR STUDENTS' OBSERVATIONS

Subject No.	Order of Pitches 1st	2nd	3rd	Amount of Light in Footcandles	Visual Perception Rankings 1st	2nd	3rd
(Day 1)							
#1	White	Yellow	Orange	5000	Orange	Yellow	White
#2	Orange	Yellow	White	5000	Yellow	White	Orange
#3	White	Orange	Yellow	4800	White	Yellow	Orange
#4	Yellow	Orange	White	4800	Orange	White	Yellow
#5	White	Orange	Yellow	4800	Orange	Yellow	White
(Day 2)							
#6	Orange	Yellow	White	600	Yellow	White	Orange
#7	Yellow	Orange	White	600	Yellow	Orange	White
#8	Yellow	White	Orange	400	Orange	Yellow	White
#9	Yellow	White	Orange	400	Orange	White	Yellow
#10	White	Yellow	Orange	1200	Yellow	Orange	White
(Day 3)							
#11	White	Orange	Yellow	1000	Orange	White	Yellow
#12	Orange	White	Yellow	800	Orange	Yellow	White
#13	Orange	White	Yellow	1000	Orange	Yellow	White
#14	Orange	Yellow	White	1100	Yellow	Orange	White
#15	Yellow	White	Orange	1400	Yellow	White	Orange

APPENDIX G

RAW DATA FOR BASEBALL PLAYERS' OBSERVATIONS

RAW DATA FOR BASEBALL PLAYERS' OBSERVATIONS

Subject No.	Order of Pitches 1st	2nd	3rd	Amount of Light in Footcandles	Visual Perception Rankings 1st	2nd	3rd
#1	White	Orange	Yellow	3600	Yellow	Orange	White
#2	Orange	White	Yellow	3600	White	Orange	Yellow
#3	Yellow	Orange	White	3600	White	Orange	Yellow
#4	Orange	Yellow	White	3400	Yellow	White	Orange
#5	Yellow	White	Orange	3400	Yellow	White	Orange

APPENDIX H

RAW DATA FOR THE BASEBALL HITTERS

RAW DATA FOR THE BASEBALL HITTERS

Player A--Trial No. 1

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Orange	1	400	35	61.65
	2	300	10	12.59
	3	300	17	30.99
	4	300	37	3.75
	5	240	75	- 30.16
	6	240	30	12.59
	7*			
	8*			
	9	200	42	23.78
	10*			
Yellow	1*			
	2*			
	3	200	22	- 5.14
	4	200	30	23.18
	5	200	33	33.28
	6	200	30	- 35.16
	7	200	10	28.60
	8	200	20	- 41.53
	9	200	35	- 38.02
	10	200	40	72.96
White	1*			
	2	100	0	15.23
	3	100	2	34.17
	4	100	60	- 17.51
	5*			
	6	100	30	34.24
	7	100	30	22.22
	8*			
	9	100	30	109.88
	10	200	10	27.43

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player A--Trial No. 2

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
White	1	320	36	37.39
	2	320	61	- 9.58
	3	320	55	72.94
	4	330	35	18.95
	5	310	4	20.85
	6	310	6	40.57
	7	310	115	13.01
	8	300	4	15.15
	9	300	0	19.77
	10	300	23	25.00
Orange	1	320	23	- 13.77
	2	340	0	- 1.30
	3	350	24	20.61
	4	350	20	- 2.24
	5**			
	6	350	4	26.79
	7	340	12	- 7.64
	8	330	17	1.62
	9	330	8	11.11
	10*			
Yellow	1*			
	2	310	21	17.15
	3	320	24	26.09
	4	330	13	29.15
	5	330	4	17.48
	6	340	17	42.93
	7	340	24	17.85
	8	340	8	- 12.35
	9	340	26	3.55
	10	340	13	14.71

*No Film Analysis

**Swung and Missed Pitch

RAW DATA FOR THE BASEBALL HITTERS

Player A--Trial No. 3

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Yellow	1	320	20	- 23.96
	2	310	36	- 33.60
	3	300	8	24.22
	4	300	25	26.06
	5	300	58	- 6.23
	6	300	75	- 5.24
	7	300	41	20.10
	8	300	10	14.54
	9	300	7	- 33.61
	10	300	16	- 26.70
White	1	250	4	40.14
	2	250	18	15.81
	3	270	5	32.00
	4	260	11	25.34
	5	250	8	18.01
	6	240	5	40.85
	7	230	8	26.10
	8	210	37	46.46
	9	210	35	33.18
	10	210	23	- 4.38
Orange	1	250	37	69.12
	2	250	25	23.28
	3	250	36	33.08
	4	180	7	21.29
	5	190	5	- 68.70
	6	190	65	54.42
	7	200	20	38.48
	8	200	20	10.77
	9	200	20	- 31.18
	10*			

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player B--Trial No. 1

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Yellow	1*			
	2	160	65	- 62.65
	3	160	170	- 16.80
	4	200	31	8.88
	5	160	55	- 11.96
	6	160	40	12.75
	7	160	55	42.68
	8	200	7	12.24
	9	200	15	5.93
	10	200	30	3.08
White	1	200	15	- 12.96
	2*			
	3*			
	4*			
	5	200	57	26.78
	6	200	32	15.93
	7	200	150	17.12
	8	200	31	26.01
	9	200	141	- 0.30
	10*			
Orange	1	200	34	45.20
	2	200	19	27.88
	3	200	145	11.53
	4	200	11	7.22
	5	200	43	41.14
	6*			
	7	200	31	10.07
	8*			
	9	200	21	- 10.73
	10	200	17	- 18.50

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player B--Trial No. 2

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Orange	1	1600	37	14.99
	2	1500	40	10.76
	3	1400	42	17.87
	4	1400	8	5.73
	5	1600	37	11.26
	6	1600	7	- 0.55
	7	1600	43	- 3.53
	8	1600	11	0.17
	9*			
	10	1400	9	- 7.37
Yellow	1	1500	38	22.45
	2	1400	12	- 18.26
	3*			
	4	1600	36	- 74.52
	5	1600	36	30.08
	6	1600	37	37.73
	7	1600	40	11.37
	8	1700	18	13.27
	9	1800	6	17.10
	10	1800	10	19.40
White	1	2200	34	40.28
	2	2200	4	31.17
	3	2200	37	- 21.44
	4	1900	32	20.80
	5	1900	3	43.47
	6	1800	21	28.09
	7	1800	43	8.38
	8	1700	22	15.72
	9	1600	19	22.63
	10	1500	23	19.82

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player B--Trial No. 3

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
White	1*			
	2	290	41	11.69
	3	290	36	- 1.68
	4	290	34	- 2.20
	5**			
	6*			
	7	290	37	14.92
	8	290	37	3.13
	9*			
	10	300	22	11.15
Orange	1	300	62	1.77
	2	300	17	- 2.07
	3	290	34	8.52
	4	290	39	14.55
	5	290	10	40.42
	6	280	156	- 9.30
	7*			
	8*			
	9	280	20	2.70
	10	290	36	21.01
Yellow	1	310	152	- 27.13
	2	320	38	23.91
	3	310	162	1.50
	4	310	22	- 2.22
	5	310	4	- 3.70
	6	300	38	6.28
	7	300	20	3.52
	8	300	59	26.69
	9	300	43	19.07
	10	310	38	0.39

*No Film Analysis

**Swung and Missed Pitch

RAW DATA FOR THE BASEBALL HITTERS

Player C--Trial No. 1

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
White	1	200	55	- 22.48
	2*			
	3	200	5	24.37
	4	200	19	49.44
	5	200	20	- 10.99
	6	200	7	- 23.74
	7	200	7	15.73
	8	200	17	36.41
	9	200	32	- 13.23
	10**			
Orange	1	240	23	12.43
	2*			
	3	240	13	12.74
	4	240	14	18.06
	5	240	10	1.80
	6	240	32	- 15.73
	7	240	25	- 3.05
	8	240	41	11.63
	9*			
	10	240	26	23.09
Yellow	1	240	8	8.73
	2	240	18	18.68
	3	240	20	- 16.92
	4	240	23	8.30
	5	240	22	13.84
	6	240	7	- 5.36
	7*			
	8	240	6	7.76
	9*			
	10	240	10	24.15

*No Film Analysis

**Swung and Missed Pitch

RAW DATA FOR THE BASEBALL HITTERS

Player C--Trial No. 2

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Yellow	1	1800	4	40.14
	2	1800	22	6.31
	3	2200	36	- 5.45
	4	2200	34	- 13.60
	5	2000	5	28.63
	6	2000	7	23.92
	7	2000	2	33.18
	8	2000	35	- 20.06
	9	2200	5	24.46
	10	2000	20	- 14.52
White	1	1600	7	- 7.89
	2	1200	21	40.01
	3*			
	4	1600	5	17.22
	5	1600	21	3.29
	6	1600	42	- 25.70
	7	1600	10	- 15.20
	8	1800	33	17.46
	9	2400	23	0.64
	10	2200	2	11.26
Orange	1	2400	45	12.18
	2	2400	23	32.42
	3*			
	4	2400	0	11.56
	5	2200	20	4.05
	6	2200	33	- 14.61
	7	2000	13	18.36
	8	2000	1	30.92
	9*			
	10	2000	22	110.11

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player C--Trial No. 3

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Orange	1	235	0	- 29.33
	2	250	138	- 1.08
	3	250	20	3.20
	4	260	20	- 0.56
	5	260	17	23.06
	6	250	22	11.29
	7	250	20	- 5.19
	8*			
	9	220	29	14.46
	10*			
Yellow	1	240	68	52.74
	2	250	62	- 18.21
	3	250	36	- 3.11
	4	260	19	33.76
	5	260	35	26.24
	6	260	36	24.70
	7	260	10	19.10
	8	260	26	32.80
	9	260	18	- 6.17
	10	260	23	13.47
White	1	270	5	10.68
	2	270	18	42.83
	3	270	23	19.63
	4	270	3	28.41
	5	270	32	12.20
	6	270	36	29.97
	7	270	32	30.88
	8	270	21	47.55
	9	280	5	32.31
	10	290	35	34.76

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player D--Trial No. 1

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
White	1	340	7	40.25
	2	300	24	23.32
	3	300	27	33.35
	4	300	20	13.73
	5	300	30	20.32
	6	300	28	11.06
	7	300	29	29.58
	8	300	8	30.56
	9	300	30	21.92
	10	340	18	37.90
Orange	1	300	7	19.41
	2	400	9	9.03
	3	400	16	23.75
	4*			
	5	400	9	6.32
	6	400	32	- 0.46
	7	400	21	13.51
	8	400	15	- 14.00
	9	400	45	55.54
	10	400	23	12.15
Yellow	1	400	23	21.00
	2	400	21	11.63
	3	400	21	40.12
	4	400	22	25.74
	5	400	18	32.71
	6	400	15	10.74
	7	400	11	21.02
	8*			
	9	400	20	21.75
	10	400	42	- 5.95

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player D--Trial No. 2

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Yellow	1	260	40	- 21.26
	2	260	8	- 32.72
	3	260	34	13.93
	4	260	36	33.50
	5	240	23	8.66
	6	230	22	- 20.79
	7	230	26	22.54
	8	220	16	16.53
	9	220	52	- 40.91
	10	210	17	17.70
White	1	190	37	23.84
	2	190	22	25.83
	3	180	10	25.60
	4	180	22	20.77
	5	180	11	40.69
	6	180	25	25.46
	7	190	10	38.07
	8	190	20	39.10
	9	200	33	20.48
	10	230	24	39.96
Orange	1	200	20	41.94
	2	210	21	18.83
	3	230	55	- 11.01
	4	240	7	23.85
	5	260	55	- 18.72
	6	270	2	29.27
	7	280	14	43.86
	8	270	17	2.45
	9	250	12	29.02
	10	260	36	- 13.18

RAW DATA FOR THE BASEBALL HITTERS

Player D--Trial No. 3

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Orange	1	250	23	42.45
	2	250	5	6.75
	3	250	6	- 5.08
	4	250	10	12.92
	5	250	11	- 3.34
	6	250	45	0.53
	7	240	8	18.45
	8	240	5	12.94
	9	220	19	10.31
	10	220	12	20.61
Yellow	1	220	36	25.77
	2	220	17	19.20
	3	210	16	17.39
	4	210	7	26.15
	5	210	4	23.58
	6	210	3	54.18
	7	210	26	4.23
	8	210	21	25.58
	9	240	3	34.68
	10	250	38	36.53
White	1	250	13	43.15
	2	250	8	26.05
	3	250	11	8.20
	4	250	3	13.20
	5	250	27	16.80
	6	250	19	18.41
	7	250	5	10.99
	8	250	23	27.87
	9	250	12	14.92
	10*			

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player E--Trial No. 1

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
White	1*			
	2*			
	3	1700	45	13.22
	4	1700	5	30.65
	5	1700	7	37.95
	6	1700	19	43.15
	7	1600	41	- 10.34
	8	1400	42	22.07
	9	1400	12	45.89
	10	1400	36	29.52
Orange	1	1300	4	42.24
	2	1300	17	21.65
	3	1300	3	30.40
	4	1400	42	28.26
	5	1400	4	84.01
	6	1400	0	41.16
	7	1600	4	48.72
	8	1600	28	13.02
	9	1600	7	15.22
	10	1600	43	- 1.68
Yellow	1	1800	20	14.75
	2	1800	10	22.19
	3	1800	0	20.97
	4	2000	3	22.67
	5	2200	43	6.56
	6	2200	9	24.24
	7	2000	16	- 23.37
	8	1600	5	11.27
	9	1400	10	34.17
	10	1000	18	21.64

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player E--Trial No. 2

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Yellow	1	460	19	- 0.47
	2	470	40	18.45
	3	470	25	33.44
	4	470	35	31.23
	5	470	53	32.77
	6	470	42	39.80
	7	320	6	49.92
	8	320	41	27.24
	9	320	23	28.35
	10	320	30	16.76
White	1	310	72	- 14.11
	2*			
	3	290	10	30.28
	4	290	55	- 2.39
	5	290	32	39.08
	6	300	53	54.99
	7	300	65	- 16.46
	8	300	36	- 22.37
	9	300	17	34.33
	10	300	47	27.13
Orange	1	300	36	36.27
	2*			
	3	300	35	43.36
	4	300	6	32.47
	5	290	7	39.29
	6	285	8	15.80
	7	285	33	17.38
	8	270	20	24.96
	9	270	55	73.93
	10	270	9	39.78

*No Film Analysis

RAW DATA FOR THE BASEBALL HITTERS

Player E--Trial No. 3

Color	Pitch No.	Amount of Light (in Footcandles)	Angle of Ball Off Bat (in Degrees)	% Difference
Orange	1	150	41	70.80
	2	150	10	10.32
	3	150	34	54.77
	4	150	5	- 18.25
	5	150	21	51.82
	6	160	37	- 5.30
	7	160	52	38.35
	8	170	52	10.47
	9	170	32	13.21
	10	170	22	37.94
Yellow	1	200	9	15.29
	2	200	23	30.32
	3	200	20	22.59
	4	200	18	28.49
	5	210	32	43.37
	6	210	8	- 3.50
	7	210	32	9.57
	8	210	32	4.23
	9	190	40	107.41
	10	200	37	52.49
White	1	180	10	26.94
	2	190	22	5.60
	3	180	37	16.62
	4	180	24	18.25
	5	180	180	30.25
	6	200	22	13.79
	7*			
	8	210	20	16.16
	9	210	6	14.16
	10*			

*No Film Analysis

APPENDIX I

SUMMARY OF PERCENTAGE DIFFERENCE SCORES FOR THE BASEBALL HITTERS

SUMMARY OF PERCENTAGE DIFFERENCE SCORES FOR THE BASEBALL HITTERS

Player A	Yellow	Orange	White
Trial #1	4.77	16.46	32.24
#2	17.40	4.40	25.41
#3	4.44	16.73	27.35
Mean	8.87	12.53	28.33
Total No. Hits	27	24	27

Player B	Yellow	Orange	White
Trial #1	- 0.65	14.23	12.10
#2	6.51	5.48	20.89
#3	4.83	9.70	6.17
Mean	3.56	9.80	13.05
Total No. Hits	28	25	22

Player C	Yellow	Orange	White
Trial #1	7.40	7.62	6.94
#2	10.30	25.62	4.57
#3	17.53	1.98	28.92
Mean	11.74	11.74	13.48
Total No. Hits	28	24	27

Player D	Yellow	Orange	White
Trial #1	19.86	13.92	26.20
#2	- 0.28	14.63	29.98
#3	26.73	11.65	19.95
Mean	15.44	13.40	25.38
Total No. Hits	29	29	29

Player E	Yellow	Orange	White
Trial #1	15.51	32.30	26.51
#2	27.75	35.92	14.50
#3	31.03	26.41	17.72
Mean	24.76	31.54	19.58
Total No. Hits	30	29	25

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