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EFFECTS OF SELECTED COLORS ON REACTION TIME AND RACQUETBALL WALL VOLLEY PERFORMANCE

Middle Tennessee State University D.A. 1984

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EFFECTS OF SELECTED COLORS ON REACTION TIME AND RACQUETBALL WALL VOLLEY PERFORMANCE

Michael R. Pruitt

A dissertation presented to the
Graduate Faculty of Middle Tennessee State University
in partial fulfillment of the requirements
for the degree Doctor of Arts

August, 1984

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EFFECTS OF SELECTED COLORS ON REACTION TIME

AND RACQUETBALL WALL VOLLEY PERFORMANCE

APPROVED:

Graduate Committee

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Major Professor

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Minor Professor

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Member of Committee

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Head of Physical Education Department

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Dean of Graduate School

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ABSTRACT

EFFECTS OF SELECTED COLORS ON REACTION TIME AND RACQUETBALL WALL VOLLEY PERFORMANCE

by Michael R. Pruitt

The purpose of this study was to determine if any of four selected colors produced a faster reaction time and if any of the four selected colored racquetballs produced a better performance on a wall volley test. The colors used in this study were blue, green, fluorescent orange, and fluorescent yellow. Twenty-three members of two beginning racquetball classes at Middle Tennessee State University during the spring of 1984 were used as subjects. All subjects were tested and found to be free of color blindness. A reaction time test using four different colored light bulbs hung at eye level with a solid white foreground was given to all subjects using an automatic performance analyzer. After selected colors were applied to racquetballs, wall volley tests were given, two tests per subject per color. Statistical procedures used were analysis of variance, correlated $\underline{t}$ test, and Pearson Product-Moment Correlation Coefficient. The primary findings of this study included: a significant difference in reaction time scores when comparing blue with orange, blue with yellow, and green with yellow; a significant difference in wall

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volley scores when comparing blue with green, and blue with orange; there was no significant relationship between reaction time scores and wall volley scores in this study. As a result of this study, the author suggests that green and fluorescent orange racquetballs would be superior to blue during racquetball play for students enrolled in a beginning racquetball class. Furthermore, fluorescent yellow, while not significantly better than blue, could prove beneficial to play.

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Finally, the author wishes to thank his beloved wife, Christine, who supplied assistance, understanding, and support during the preparation of this dissertation.

M. R. P.

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Chapter I

Introduction

In recent years the United States has experienced a physical fitness boom. During this boom racquetball has experienced phenomenal growth. Since the game was invented in 1950 (Carlson, 1979), various colors of balls have been used. There is some disagreement (Allsen & Witbeck, 1981; Stafford, 1975) about the color of the first ball. Some of the colors that have been used through the years are pink, blue, green, black, and red. Can a different colored ball improve playing conditions and possibly even scores? The colors of balls, in most sports, have been left up to the inclination of the manufacturer. Until recently, manufacturers' decisions for producing various colored balls have been based on aesthetic beauty, saleability of product, and player preference and not on results of scientific experimentation including skill improvement experiences. Many balls or projectiles, in sports, have traditionally been white. In recent years, different colors have also been used in tennis, baseball, golf, soccer, and table tennis. Studies (Morris, 1976; Puhl, 1978) have shown that various colors of balls do affect athletic performance in selected sports. If visual perception is better with a particular color of ball

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in some sports, would the same hold true for a specific colored ball in racquetball? Because of a desire by the writer to discover ways to improve performance in sports, a study of this nature seems warranted. The results of this study could provide valuable information for physical education teachers, coaches, and manufacturing companies as well as consumers.

Statement of the Problem

The purpose of this study was to determine if any of four selected colors produce a faster reaction time, and if any of those same four colors produce a better performance on a racquetball wall volley test. The four colors used were (a) blue, (b) light green, (c) fluorescent yellow, and (d) fluorescent orange.

Hypotheses

The major hypotheses of this study were:

1. There will be no significant differences in the reaction times of the beginning racquetball players when using selected colored light bulbs.

2. There will be no significant differences in the wall volley test results in regard to ball color when used by the racquetball players.

3. There will be no significant relationship between reaction time scores and racquetball volleying scores of the racquetball players.

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Significance of the Study

The results and conclusions of this study may give insight into ways of improving performance. It has been implied that players will improve their performance as long as external factors--such as equipment, facilities, and so forth--improve. If ball color plays a role in player performance, then there is a need for this study.

Ray Mortvedt (Personal Communication, January 19, 1984), director of engineering for Ektelon Corporation, replied that his company's primary objective in ball color selection is to maximize a player's visual perception. Ektelon's color research, according to Mortvedt, is strictly subjective based on player feedback. Other racquetball companies were contacted by letter but failed to respond to the question of ball color selection.

If this study indicates that different colored balls do enhance tracking ability, the performance of players should improve with their continued regular use. The results of this study could be a starting point for other studies designed to improve color perception by spectators, officials, and umpires.

Limitation of the Study

1. Subjects were limited to those with normal color vision, as determined through use of the Ishihara Color-Blind Test.

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2. Subjects were limited to those individuals enrolled in selected beginning racquetball classes at Middle Tennessee State University during the spring semester of 1984.

3. Skill testing took place in four racquetball courts located on the campus of Middle Tennessee State University.

4. The background color was limited to white in the four courts.

5. The study was limited to four colors of light bulbs and racquetballs--light green, blue, fluorescent yellow, and fluorescent orange.

6. The study was limited to the .05 level of confidence for determining acceptance or rejection of the null hypotheses.

Definition of Terms

1. Reaction Time-the interval between presentation of the stimulus and the first indication of response.

2. Light Green-a green color much lighter than the old dark green racquetballs made in the past. This light green will be referred to as green in the remainder of the study.

3. Dynamic Visual Acuity-the ability of a player to resolve details of an object in motion.

4. Static Visual Acuity-the ability of a player to resolve details of an object which is stationary.

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Chapter II

Review of Related Literature

Introduction

There have been few studies on the relationship of colored moving objects to reaction time and visual perception. In order to form a basis for this study, the following research sections will be included in this chapter: tracking ability, color perception, wall volley tests, color blind tests, and reaction time.

Tracking Ability

Since the performance of racquetball players depends on the ability to track the ball visually, the color of the ball may play an important part in this performance. Poulton (1974) stated that "tracking is concerned with the execution of accurate movements at the correct time" (p. 3). Factors which might affect the execution of accurate movements (Solotest, 1977) could be the lightness darkness contrast of the ball with respect to the background against which it is seen and the contrast in hue of that object.

One of the few studies in recent years on the role of color in the control of moving objects was done by Shick (1975) on the role of color in softball throwing accuracy. Even though objects of different colors appeared to be at

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different distances, it was found that changing the target color had no measurable effect on throwing accuracy. This study was based upon a stationary target.

There are some general recommendations made by Gavriysky (1970) regarding color contrast when choosing ball color. He suggests a stronger contrast between ball and sports arena, painting goal posts in clearly visible or contrasting colors, and using visual signals (light or color flashes) instead of a whistle. Rachun (1969), with an opposing point of view, claims that color blindness is not known to affect athletic performance. If this is true, color contrast would not help the performance of individuals with normal color vision nor would it hurt those who are color blind. Goodwin (1973) claims that color recognition takes place with a greater time delay than object tracking and therefore is unrelated to it. He implies that there will be recognition of movement before recognition of color.

Ridenour (1977) studied the influence of object size, distance, direction, height, speed, and sex on success in striking a moving ball with a paddle. She concluded that there was a significant influence in all areas except object size. Ridenour (1974) also suggests other variables which could affect striking or catching an object: ball color, background complexity, shape, trajectory, available auditory cues, or verbal instruction concerning direction.

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The ability to track objects smoothly with the eyes is not necessarily correlated with sports performance. Trachtman (1974) showed that tracking ability in Little League baseball players did not correlate with their ability (batting averages) to play the game. This suggests that care should be taken when comparing visual performance results to eye-hand coordination.

In comparing past studies on the correlation between static and dynamic visual acuity, Burg (1966) stated that some of the primary reasons for lack of consistency between the studies were "small sample size and excessive homogeneity of the sample" (p. 460). Burg and Hulbert (1961) found that there was a low but significant correlation between static visual acuity and dynamic visual acuity. The study was replicated in 1966 with "an extremely large, heterogeneous group" (p. 465). The correlations were found to be significantly higher in the 1966 study.

Hammerton and Tickner (1970b) experimented with various backgrounds and their effect on tracking ability. In this study the subjects moved a sighting device to keep a graticule on a moving object. Both realistic and blank backgrounds were used for the target. The subjects' performances in the two conditions were then compared. It was found that an inferior performance resulted when using the blank background. The presence of objects in the background should not hinder but should help tracking of an object. Applying the results

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of this study, one might conclude that in a glass racquetball court the background might help in the tracking of the ball instead of hindering it.

Although a realistic background may be helpful, an object could momentarily blend into the background. When an object loses visibility, tracking ability is severely hindered although recovery is quick when visibility returns (Hammerton & Tickner, 1970a). "Losing sight of the ball will probably have the worst effect on player performance if it happens immediately before the ball is to be hit" (Solotest, 1977, p. 11).

Solotest Corporation (1977), in a study prepared for Wilson Sporting Goods Company, stated that "the trackability of a ball depends on its contrast with the background against which it is seen, and this contrast depends on the color of the ball, the color of the background, and the lights illuminating both" (p. 13). Other researchers (Battig, Greg, Nagel, Small, & Brogden, 1954; Voss, 1955) have found that brightness of the object might be important in determining proficiency of tracking.

Color Perception

Color is defined (*Webster's Third New International Dictionary*, 1968) as "any of manifold phenomena of light (as red, brown, pink, gray, green, blue, white) or visual sensation or perception that enables one to differentiate objects even though the objects may appear otherwise identical

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(as in size, form, or texture)" (p. 447). Color is so commonplace in the lives of individuals, except for those who are color blind, that little conscious thought is given to it each day. Most people admire color only occasionally, such as when they see a beautiful sunset or different colored leaves on a fall day.

Gavriysky (1969) suggested that different colors affect our bodies in specific ways. He found that green soothes and red stimulates. Black is oppressive, whereas, white, yellow and yellowish green have a tonic effect. Warm colors (red, yellow, and orange) activate visual and physiological processes and cool colors (blue and green) retard them (Birren, 1961). Red and green can be identified in poor light more easily than yellow or blue, although the opposite is true in bright light.

> In complete darkness, the eyes see dark gray, but not black. For black does not exist except as a sensation that accompanies or follows other colors; the lighter those colors are the deeper the black will appear. Black is blackest in contrast to white. (Mueller & Rudolph, 1969, p. 136).

Color seems to affect the judgment of distance of objects (Johns & Sumner, 1948; Mount, Case, Sanderson, & Brenner, 1956; Pillsbury & Schaefer, 1937; Taylor & Sumner, 1945). At a constant distance (Johns & Sumner, 1948) bright colors (white, yellow, and green) appear nearer than dark

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colors (red, blue, and black). Whiting (1969) emphasized that while precise judgment of distance of objects is important in everyday life, it is even more so in ball games--particularly fast ball games where so many precise predictions have to be made. This would be especially true in a fast moving game like racquetball.

Hill (1958) reported that yellow, not red, was the best color for all purposes of safety. In a test of Army personnel, the color yellow was identified four to five times more often than any other color. It was also found that yellow was recognized four times faster than red. Yellow (Birren, 1961) has the highest visibility of any color and should be seen as the largest and nearest of colors. Statistics (Gavriysky, 1969) indicate that red and yellow cars are the least involved in road accidents.

Fluorescent colors have received considerable attention over the past few years. Visibility protection by daylight fluorescent apparel (Day-Glo, 1972) has significantly decreased injuries and deaths of hunters. Tests by the Massachusetts Division of Fisheries and Game, the American Optical Company, and the U. S. Strategic Army Command proved that Day-Glo blaze orange was the color most likely to insure safety for hunters. Blaze orange was the only color, in these tests, detected by persons with normal vision. Since animals are color blind, none of the sport is lost.

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Fluorescent orange hunting hats and vests (Bell, 1972) are eye-catching and conspicuous against any background.

In a test to compare the effectiveness of fluorescent signs versus regular signs, the Point of Purchase Advertising Institute (1978) found fluorescent signs to be approximately 50% more productive in unit sales. The regular orange signs increased sales 162% and the fluorescent orange increased sales 236%. In another study of outdoor advertising boards, Telecom (1978) reported that fluorescent colors are seen 75% faster than boards using conventional colors.

In Coast Guard tests (Dwyer, 1973), a fluorescent orange flag could be seen on the horizon when the boat was no longer visible. Dwyer also revealed that brilliant fluorescent colors are now suggested for use on locomotives for increased visibility at highway grade crossings.

Solotest (1977) examined the possibility of using fluorescent colored tennis balls under different playing conditions. They made the following suggestions:

1. Outdoors, In Sunlight: A ball covered with large patches of red, yellow, and orange fluorescent dyes is recommended for this environment. This type of ball will fuse into a brilliant yellow when the ball spins too fast for the colors to be seen separately.

2. Outdoors, In Overcast Weather: The same ball recommended for outdoors in sunlight is also suggested here.

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A white ball would not work very well under these conditions because the ball would blend into the white clouds.

3. Outdoors, At Night, With Lights: Multiple colors are unnecessary because the background will likely be the night sky or dark court. A fluorescent yellow or white ball will probably work best.

4. Indoors, At Night, With Lights: Under these conditions, the color of the ball is less important than its lightness. A yellow or white ball is recommended.

Penn Athletic Products (1977) developed a high visibility test to determine the best color for tennis balls under various playing conditions. The results of this study were:

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

2. Orange balls most visible against blue background under all conditions.

3. Orange balls most visible against dark gray background under most conditions (white balls easier to see in dim light).

4. Orange balls most visible against green background under some conditions (yellow balls most visible at high speed).

Leonard (1984) indicated that white tennis balls are an endangered species and if it were not for the remaining

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few grass courts, U. S. manufacturers would probably discontinue producing them. Less than 5% of balls currently sold in this country are white. At least 90% (Stine, 1978) of the tennis balls made by Penn, Wilson, Bancroft, Dunlop, and Winn are yellow.

Through the years, the game of baseball has consistently used a white ball. Charlie Finley (Time, 1975) believed that an orange ball was easier to see than a white one, particularly at night. An exhibition game was played between the California Angels and the Oakland A's with an orange baseball in 1973 (Watson, 1973). Davis (1978) studied the effects yellow, orange, and white baseballs have upon the visual perception and hitting effectiveness of college baseball players. A visual perception ranking by the subjects showed a preference for the yellow and orange baseballs over the white ball. However, the results of this study indicated that there was no significant difference in hitting effectiveness using the three colors.

Research (Isaacs, 1980a, 1980b) reveals that preferred color might be an influencing factor in performance. Results of these studies by Isaacs (1980a, 1980b) showed that both boys and girls, between ages 7 and 8, tended to catch their preferred colored ball significantly better than their non-preferred colored balls. Color preference studies (H. Smith, 1970) show that blue is the favorite color for both boys and girls followed by red and orange.

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Morris (1976) found that both blue and yellow balls were caught significantly better than white balls when testing the effects of ball and background color on the catching performance of young children. He further concluded that the children's highest catching scores were obtained when the blue balls were projected against a white background. Puhl (1978) studied the effects of ball color, background color, and sex on the reaction times of kindergarten children. She discovered that a blue ball against a white background produced the quickest reaction times.

Schoney (1973) found different results when she investigated the effect of color on the catching performances of 8.5- to 11.5-year-old boys and girls. Three colors of balls were used in this study: red, green, and blue. No significant effect on catching performances was found when the three colors were compared against a white background.

Wall Volley Tests

Wickstrom and Larson (1972) suggest than an appropriate technique for measuring the achievement of racquetball skills is the wall volley test. They decided that several desirable characteristics are contained within a wall volley test. Included in this list are: relative ease of administration, the capacity to discriminate among ability levels, and a high degree of similarity to gamelike conditions. They developed a wall volley test in 1972. During the administration of this test, the subject must stand behind a restraining line

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that is 3.048 m from and parallel to the front wall. Three trials of 30 sec was given and the score was the total number of hits against the front wall. Validity and reliability coefficients have not been established for this test.

Hensley, East, and Stillwell (1979) developed a two-item racquetball skills test. The two-item test included a short wall volley test and a long wall volley test. Two 30-sec trials were given for the short wall volley, with the subject standing behind the short line while attempting to volley the ball against the front wall. The long volley was administered in the same manner except the subject had to stand behind a restraining line 3.6576 m in back of and parallel to the short line. The sum of the two 30-sec wall volleys determines the final score. A reliability of .82 for women and .76 for men was found for the long wall volley. Results for validity coefficients for men and women were .86 for the long volley test and .79 for the short volley test.

Several handball tests have been developed through the years which can be used equally well for racquetball. Cornish (1949) investigated the value of five handball skill items. One of the five items was a 30-sec wall volley test. Administration of this test is similar to the Wickstrom and Larson (1972) test with the exception of the restraining line being 4.572 m from the front wall. Also the subject is permitted to step into the front court to stroke the ball, but must return to the restraining line for the next stroke.

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Reliability was not reported, but a validity correlation coefficient of .53 was found.

In 1967 Tyson (Collins & Hodges, 1978) designed a handball skill test for college men. Reliability coefficients were .82 while validity coefficients were found to be .87. "The Tyson test appears to be the most valuable handball skills test found in the literature study" (Collins & Hodges, 1978, p. 290). It is suggested that a practice drill immediately prior to testing might help to increase the reliability value.

Color Blindness

Color blindness (Mueller & Rudolph, 1969) is a loose term because it implies a complete lack of ability to see color. Total color blindness is extremely rare. However, some form of defective color vision is found in approximately 8% of men and less than 1% of women. There are several tests for color blindness. Some of these include: Jenson test, American Optical Company's Pseudo-Isochromatic Plates, Isihara test, Ortho-Rater test, and Keystone color vision test.

Foster (1946) tested 200 men between the ages of 17 and 56 with the Jenson, Pseudo-Isochromatic Plates, and Isihara tests. She found that the Isihara and Pseudo-Isochromatic Plates were in close agreement with each other, while the Jenson showed far less agreement with either of the other tests. The jenson test was limited to three or four plates

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and was considered to be too unreliable for individual diagnosis.

Kephart and Tieszen (1951) compared the Ortho-Rater color vision test to the Ishihara and the Pseudo-Isochromatic Plates. They found the Ishihara and Pseudo-Isochromatic Plates to be valid and reliable while the Ortho-Rater test had a tendency to misclassify subjects with normal color vision.

The Keystone test consists only of four color plates. Chapanis (1950) considers this test to be neither valid nor reliable compared to other color blind tests.

The Ishihara test and Pseudo-Isochromatic Plates have become accepted as valid detectors of defective color vision (Boice, Tinker, & Paterson, 1948). Dr. Jean Hawkins (personal communication, March 5, 1984), optometrist from Murfreesboro, Tennessee, replied that the Ishihara test is probably the most widely used color blind test.

Reaction Time

Many studies in physical education, psychology, and other fields have explored various aspects of reaction time. The primary concern of psychologists has been with response measurement as it relates to learning, whereas physical educators have been concerned with methods of improving reaction time and how this would influence physical performance. Johnson and Nelson (1969) stated several factors which

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influence reaction time. Some of these include: the sense organ involved, the intensity of the stimulus, the preparatory set, muscular tension, motivation, practice, the response required, fatigue, and one's general state of health. Some people react quickly but move slowly, and others react slowly but move quickly. Thus, reaction and movement are very important to consider when talking about the performance of a skill. In order to fully understand results of studies which deal with reaction and movement time, it is necessary to understand the difference between the two terms. Reaction time is defined (DeVries, 1980) as "the interval between presentation of the stimulus and the first sign of response" (p. 102). Movement time is defined as "the interval between the start and the finish of a given movement" (DeVries, 1980, p. 102). Response time is "the total time taken to initiate and complete a response, and includes both reaction time and movement time" (Robb, 1972, p. 86).

The relationship between reaction time and movement time is an area of disagreement among researchers. Some studies (Henry, 1961; Hodgkins, 1963; Norrie, 1974; L. Smith, 1961) have indicated that a very low correlation exists between the two. Others (Hipple, 1954; Kerr, 1966; Pierson, 1959; Slater-Hammel, 1952) report that there is a significant relationship between reaction time and movement time. Even though the latter studies show statistically significant relationships,

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the majority of research generally supports little or no relationship. Specificity versus generality is a question often asked in regard to reaction and movement time. Will a subject responding quickly with an arm perform equally well with a leg? Studies (Clark & Glines, 1962; Henry & Rogers, 1960; Lotter, 1960) seem to indicate a relatively high degree of specificity by limb and movement. For this reason a person may be quick in responding with an arm but slow when responding with legs.

Reaction time tests can be arranged many different ways. There are two generally accepted classifications: simple reaction time and choice reaction time. Robb (1972) gives an example of the various types:

> In a simple reaction time test (type A), the subject is asked to react to a stimulus by making a specified response. There is one stimulus and one response. Pushing a button when a light comes on, or flicking a switch after a specified sound are examples of simple reaction time tests. A timing device records the delay between the occurrence of the stimulus and the initiation of the response. Choice reaction time tests can be of two different types. In type B, the subject is asked to respond to several stimuli. Reacting to lights displayed on a panel by pushing the appropriate response key is an example. The

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> subject must learn the proper response for each stimulus. A type C test presents several stimuli but requires only one response. The subjects task is to learn when to respond to a specified stimulus. (p. 88-89)

One area of reaction time which has received considerable attention within recent years is the type of stimulus used in the measurement process. In various studies, three types of stimuli have been used: visual, auditory, and tactile. Visual refers to seeing, auditory to hearing, and tactile to feeling. Several studies (Colgate, 1968; Lawther, 1977; Sage, 1971) have shown that subjects react quickest to auditory stimuli. In the investigation by Colgate (1968), it was found that after auditory response, speed of reaction and speed of response were faster when the subjects responded to a visual stimulus than when they responded to an electroshock stimulus.

Swink (1966) found that multiple stimuli can cause a shorter response period than does a single stimulus. He reported the following ranking of the various stimuli and stimuli combinations for their effects on reaction time, listed in order from slowest to fastest reaction time: light, sound, shock, light-sound, light-shock, light-sound-shock. Mowbray and Rhoades (1959) reported similar findings.

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Another factor which has been found to have an influence on reaction time is the intensity of the stimulus. Teichner (1954) found that when the intensity of the stimulus was increased, the reaction time was shortened. He stated, "People will react more quickly up to a point, as the stimulus gets stronger. If the point is exceeded, the stimuli will tend to block performance because of the stressful nature" (Teichner, 1954, p. 133). Woodworth and Schlosberg (1954) and Vallerga (1958) agree with this concept. This finding would support the idea of making the intensity of the stimulus contrast as much as possible with the background.

The effect of warmup activities on reaction time has produced opposing views. In three separate studies (Elbel, 1940; Meyers, Zimmerli, Farr, & Baschnagel, 1969; Phillips, 1963) it was found that various warmup activities did not bring about significant changes in reaction time. A study (Sage, 1971) made in Poland found that cooling the hand with ice for 3 min produced poorer reaction times, whereas warming the hands for 10 min in a thermal box caused an improvement of reaction time.

Another factor which has an effect on reaction time is a forewarning period or a preliminary signal. Robb (1972) defines foreperiod as "the time between a warning signal and the presentation of the stimulus" (p. 87). Drazin (1961) and Rothstein (1973) found that reaction times were quicker when

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the length of the foreperiod increased. They based this on a time range of from .2 of a second to 4.5 sec. Wilson (1959) stated that if the foreperiod is too long, the subjects' readiness will fade away and if it is too short they will not have time to get ready. Munro (1951) reported that the best interval between the warning period and the stimulus is 2 sec while Sage (1971) said that between 1 and 1.5 sec is the best. Sage also expressed that reaction time is cut .05 of a second when using a preparatory command. Care should be taken that there is not a constant foreperiod for all trials (Puhl, 1978), otherwise the test will be one of anticipation rather than a test for reaction time.

Elbel (1939) conducted a study in an effort to find out which hours in the day resulted in the quickest reaction time. The results indicated that the slowest times were 12:20 p.m. and the fastest being 9:20 in the morning and 2:20 in the afternoon.

There is considerable variations (Botwinick, Brinley, & Birren, 1955; Mendryk, 1960) in the reaction times of males and females of various ages. In a study by Hodgkins (1963), it was found that between the ages of 12 and 54, speed of reaction is faster in males than it is in females. Peak speed of reaction was found to be reached between the ages of 18 and 21 by both males and females with an age range of 6 to 74. According to Henry (1961), reaction times for college women are approximately 14% slower than men.

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Thompson, Nagle, and Dobias (1958) found that a rhythmic stimulus produced nearly 10% faster reaction times than with a nonrhythmic stimulus. The validity of their method has been questioned since the experimenter started the chronoscope manually. A latter study (Wilson, 1959) showed a 6% faster time using a rhythmic stimulus.

Researchers have concluded that very little improvement in reaction time takes place after a few practice trials. Norrie (1974) reported that learning takes place only during the first 12 trials. Hodgkins (1963) found there was no significant improvement from the 1st to the 10th trial. According to these studies, a few practice trials would be advisable before conducting a test. However, it should be pointed out that too many practice trials could result in fatigue.

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Chapter III

Methods and Procedures

Introduction

The testing for this study took place in Murphy Center on the campus of Middle Tennessee State University in Murfreesboro, Tennessee, during the spring semester of 1984. Reaction time and wall volley skill testing took place at either 11:00 a.m. or 4:00 p.m. A consent form was signed by all those willing to participate in the research.

Description of Subjects

All subjects for this study were officially enrolled students in one of two beginning racquetball classes at Middle Tennessee State University. A total of 23 subjects were included in the study. Of the 23 subjects, 9 were female and 14 were male. The subjects had an age range of 18 to 23. Only subjects free from evidence of color vision deficiency as shown through use of a color plate identification test were included in the study.

Equipment

Color-blind test. The Ishihara Color Blind Test was administered to each of the subjects. Successful passing of the test was necessary before subjects were included in the study. Several studies (Boice, Tinker & Paterson, 1948;

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Foster, 1946; Kephart & Tieszen, 1951) have found the Ishihara test to be valid and reliable.

Reaction time test. Reaction machine - An Automatic Performance Analyzer (Model 631) from Dekan Timing Devices was used to test reaction time of the subjects to the four colored light bulbs. The machine had a built-in timing device.

Foreground - The foreground was composed of a white sheet hung in front of the light source. The sheet was 1.8288 m x 1.524 m.

Wall volley test. Balls - 24 Ektelon racquetballs were used during the study. Each ball was 5.715 cm in diameter and had a weight of approximately 1.4 oz. Four different colored balls were used--green, blue, fluorescent yellow, and fluorescent orange.

Stop Watch - Four stop watches were used for the 30 sec wall volley test. Each watch measured to the nearest .1 sec.

Administrative Procedures

Color-blind test. Each subject passed the Ishihara test for color blindness. The Ishihara test is a series of plates designed to give a quick and accurate assessment of color vision deficiency. The plates were tilted so that the plane of the paper is at right angles to the line of vision and are held 75 cm from the subject. The numerals which are seen on the plates will be stated by the subject

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and each answer should be given without more than a 3 sec delay. An assessment of the readings of plates 1 to 11 determines the normality or deficiency of color vision. If 10 or more plates are read normally, the color vision is regarded as normal. If only 7 or less than 7 plates are read correctly, the color vision is regarded as defective.

Wall Volley Test. The Wickstrom and Larson wall volley test was used for this study because other wall volley tests suggest a restraining line of more than 3.048 m and thus allow subjects a greater time period to react.

Directions: The subject stood behind a restraining line that was 3.048 m from and parallel to the front wall. Each testing period was begun with a hit to the front wall by the subject. The subject proceeded to volley the ball against the front wall as many times as possible within the 30 sec time period. Hits did not count if the ball bounced on the floor or if the restraining line was stepped over. If control of the ball was lost, a trained ball hander presented another ball to the subject. Either a forehand or backhand stroke was allowed during the wall volley test. The score was the total number of legal hits made in the 30 sec trial. A second trial was given after a 30 sec rest period. The final score was the best of the two trials. The subject stood behind the restraining line midway between the side walls. The counter stood behind the service line along

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the left side wall for right handed subjects and along the right side wall for left handed subjects. The timer stood .6096 m behind the counter. The person with extra racquet-balls stood 1.8288 m behind the subject, and a ball retriever was 2.4384 m from the back wall. All ball handers and ball retrievers were involved in a training session one week prior to the test. A demonstration and practice of the procedures was held during this practice session.

Reaction time test. A reaction time test was given to all subjects using a Dekan automatic performance analyzer. Subjects reacted to different colored light bulbs while standing 3.048 m away. The light bulb colors used were blue, green, fluorescent yellow, and fluorescent orange. Ten trials were given with each color. A delay start circuit was used for each trial that was adjustable from 1 to 6 sec by a control knob on the panel of the basic unit. All 10 trials were given for one color for each subject before moving on to another color. A predetermined color sequence for subjects was made for both the wall volley and reaction time tests.

Directions: Each subject was standing while taking the reaction time test. The visual stimulus (light bulb) was adjusted to eye level for each person. Time was recorded to the nearest .01 of a second. The basic unit and the tester remained behind the subject during the test. A control cord

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was used by the subject to stop the timer. The control cord was a 4.572 m cord with a button switch on one end and a plug jack on the other. The plug jack was connected to the basic unit. After a command of "Ready," the tester activated the delay start circuit. The subject was given 5 practice trials with a white light bulb before the test began. All subjects used the forefinger of their dominant hand.

Statistical Procedures

The following statistical procedures were used for this study (a) Pearson Product-Moment Correlation Coefficient, (b) analysis of variance, and the (c) correlated *t* test. The Honeywell DPS 8/44D computer system at the Middle Tennessee State University (MTSU) computer center was used for Pearson Product-Moment Correlation Coefficient and analysis of variance statistical purposes. The correlated *t* tests were computed by a calculator since a program was not available at the MTSU computer center.

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Chapter IV

Analysis of Data

Introduction

This study was designed to determine if any of four selected colors produced the fastest reaction time and if any of the selected colors produced a better performance on a racquetball wall volley test. The data obtained in this study consisted of scores made by 23 college students on reaction time and wall volley tests. Raw data and summaries for reaction time and wall volley tests can be found in Appendices D, E, F, and G. For the sake of consistency, colors are presented in sequential order throughout the study in the following order: (a) blue, (b) green, (c) fluorescent orange, and (d) fluorescent yellow.

The Ishihara test for color blindness (see Appendix A) was passed by all 23 subjects before the pretest color preference question was asked. The results of the pretest color preference (see Appendix B) showed that 9 subjects preferred blue, 8 favored fluorescent orange, 5 chose green, and only 1 selected fluorescent yellow. The fact that blue was the most preferred color does not seem too surprising, since most of the subjects may have never played with any other color. Players often prefer a color to which they are accustomed. There are no orange racquetballs available on

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the market today, and it was surprising that this color finished a close second to blue. Ninety percent (Stine, 1978) of the tennis balls made in this country are yellow. Because of the subjects' probable exposure to tennis, it was expected that there would be a high percentage of those who preferred yellow. Why did only one subject prefer yellow? Possibly because the background color was white and the contrast was not as great as it was with the other colors.

A predetermined color sequence was randomly assigned to each subject before testing began. This assured that colors and sequences equalled out across subjects. These color sequences can be found in Appendix C.

Treatment of Data

Statistically, a one-way analysis of variance was used to determine if there was a significant difference among the four colors at the .05 level of confidence. Analysis of variance tests were conducted on both the reaction time and wall volley scores.

After the analysis of variance indicated there were significant differences in both the wall volley and reaction time scores, correlated *t* tests were used. The correlated *t* tests help to identify where significant differences exist. The test results can be found in Appendices H and I. Several of the correlated *t* ratios have a negative final result. Ferguson (1966) claims that "We may ignore the negative sign of *t* and consider only its absolute magnitude" (p. 170).

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The final statistical procedure utilized in this study was a Pearson Product-Moment Correlation Coefficient to determine if relationships existed between raction time and wall volley scores. The following sets of scores were analyzed: (a) blue wall volley and blue reaction time, (b) green wall volley and green reaction time, (c) fluorescent orange wall volley and fluorescent orange reaction time, and (d) fluorescent yellow wall volley and fluorescent yellow reaction time.

Analysis of Variance for Reaction Time

The results of the analysis of variance for reaction times are given in Table 1. With an *F* ratio of 7.863, it was found that a significant difference existed at the .05 level. An *F* ratio of 3.03 was necessary for significance to occur at the .05 level. This indicated that there was a significant difference in the results between colors for reaction time. Johns and Sumner (1948) stated that at a constant distance bright colors appear nearer than do dark colors. The results of the present study would support the concept of reaction time being quicker for bright colors. Birren (1961) claims that warm colors (red, yellow, and orange) activate visual and physiological processes and cool colors (blue and green) retard them. If warm colors do activate visual and physiological processes, then reaction time should be faster. This claim by Birren is supported by the present study which found fluorescent orange and fluorescent yellow to have the quickest reaction times.

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Table 1

Analysis of Variance for Reaction Time

Source	ss	df	Mean Squares	F Ratio
Between Error	.03446300	22	.001566	
Color	.00216439	3	.0007214	7.863 *
Within Error	.00605560	66	.00009175	
Total	.04268300	91	.00009175	

* significant at the .05 level of confidence.

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Analysis of Variance for Wall Volley

In Table 2 the results of the analysis of variance for wall volley showed an *F* ratio of 3.135. This is significant at the .05 level. An *F* ratio of 3.03 was necessary for significance at the .05 level of confidence. The wall volley test involved dynamic visual acuity, which is the ability to resolve details of an object in motion. Gavriysky (1969) stated that red and yellow cars are the least involved in road accidents, which would indicate that they are easier to see. If certain colors of cars are recognized easier, would not the same be true of colored racquetballs? The evidence from the results of the analysis of variance of this study suggests that this may be true.

Correlated *t* Tests for Reaction Time

To find out where the significant difference was in the reaction time scores, correlated *t* tests were conducted on the data. Results of the correlated *t* tests on reaction time scores are given in Table 3. Of the six individual comparisons computed, three showed significant differences at the .01 level of confidence or better. The three tests were: (a) blue compared with fluorescent orange, (b) blue compared with fluorescent yellow, and (c) green compared with fluorescent yellow. The blue compared with fluorescent orange revealed a *t* ratio of 2.8583 which is significant at the .01 level of confidence in favor of the fluorescent orange. A *t* ratio of 5.2331 was found for blue compared

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Table 2

Analysis of Variance for Wall Volley

Source	ss	df	Mean Squares	F Ratio
Between Error	1934.410	22	87.9279	
Color	124.304	3	41.4348	3.135 *
Within Error	872.196	66	13.2151	
Total	2930.91	91	13.2151	

* significant at the .05 level of confidence

Table 3

Correlated t Tests for Comparison of Differences Between Means of Reaction Time Scores

1	2	N	$Mean_1$	$Mean_2$	t
Blue	Green	23	.24691	.24478	.7489
Blue	Fluor. Orange	23	.24691	.24000	2.8583 *
Blue	Fluor. Yellow	23	.24691	.23430	5.2331 *
Green	Fluor. Orange	23	.24478	.24000	1.4018
Green	Fluor. Yellow	23	.24478	.23430	4.2514 *
Fluor. Orange	Fluor. Yellow	23	.24000	.23430	1.7654

* significant at .05 level of confidence

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with fluorescent yellow which was significant at the .001 level of confidence in favor of fluorescent yellow. The green compared with fluorescent yellow analysis indicated significance at the .001 level with a $\underline{t}$ ratio of 4.2514; this also favoring the fluorescent yellow. The results of the correlated $\underline{t}$ tests clearly suggested that the fluorescent colors were the best for static reaction times as measured in this study.

Puhl (1978) found different results when she studied the effects of ball and background color on the reaction time of kindergarten children. She discovered that a blue ball against a white background produced the quickest reaction times. The results of the present study did not support Pulh's findings. Blue produced the slowest reaction time of the four colors used.

The first hypothesis for this study stated that there will be no significant difference in the reaction times of the beginning racquetball players when using selected colored light bulbs. On the basis of the results obtained in this study hypothesis one was rejected. According to the correlated $\underline{t}$ tests there were statistically significant differences in three of the six color comparisons.

The following means were obtained on the four colors for reaction time: (a) blue--.24691, (b) green--.24478, (c) fluorescent orange--.24000, and (d) fluorescent yellow--.23430. This suggests that brighter colors elicit the quickest reaction times.

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<u>Correlated *t* Tests for Wall Volley</u>

Table 4 gives the results of the correlated *t* tests on wall volley scores. Two of the six individual tests conducted indicated a significant difference at the .05 level or better. The two tests that proved to be significant were: (a) blue compared with green, favoring green, and (b) blue compared with fluorescent orange, favoring fluorescent orange. A *t* ratio of 3.1988 was found for the blue and green test which was significant at the .01 level. The blue and fluorescent orange test was significant at the .05 level with a *t* ratio of 2.1542. The results of the correlated *t* tests for wall volley scores indicated that blue was the least effective of the four colors. They also revealed that both green and fluorescent orange were significantly better than the blue.

The results of this study do not support the conclusions reached by Schoney (1973) and Morris (1976). Schoney (1973) found that there was no significant effect on catching performance when red, green, and blue balls were compared against a white background. Morris (1976) discovered that both blue and yellow balls were caught significantly better than white balls when testing the effects of ball and background color on the catching performance of young children. He further concluded that the children's highest catching scores were obtained when the blue balls were projected

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Table 4

Correlated _t_ Tests for Comparison of Difference Between Means of Wall Volley Scores

1	2	N	$Mean_1$	$Mean_2$	_t_
Blue	Green	23	26.348	29.565	3.1988*
Blue	Fluor. Orange	23	26.348	28.522	2.1542*
Blue	Fluor. Yellow	23	26.348	28.000	1.6907
Green	Fluor. Orange	23	29.565	28.522	.8273
Green	Fluor. Yellow	23	29.565	28.000	1.4475
Fluor. Orange	Fluor. Yellow	23	28.522	28.000	.4908

* significant at .05 level of confidence.

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against a white background. The results of the present study revealed that the best scores were produced when the students used the green ball.

The second hypothesis for this study was that there will be no significant difference in the wall volley test results with regard to ball color. Based upon the results of this study, this hypothesis was also rejected. According to the correlated *t* tests there was a significant difference in two of the six tests.

The following mean scores were obtained on the four wall volley colors: (a) blue--26.348, (b) green--29.565, (c) fluorescent orange--28.522, and (d) fluorescent yellow--28.000. The most popular colored racquetball being sold today is blue. According to the mean scores, the use of colors other than blue could result in improved performance. The green racquetball was the best of the four colors used in this study.

Pearson *r* for Relationship Between Reaction Time and Wall Volley Scores

The results of the Pearson Product-Moment Correlation Coefficient between reaction time and wall volley scores according to color used are listed in Table 5. Blue had the highest correlation coefficient of the colors with .438. Green had the second highest relationship with a correlation coefficient of .348; fluorescent orange was next with a .295; and fluorescent yellow was last with .147. According to Johnson and Nelson (1969), these findings show that only

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Table 5

Pearson Product-Moment Correlation Coefficients for Reaction Time and Wall Volley Scores

Color	Pearson Correlation Coefficients
Fluor. Yellow	.147
Fluor. Orange	.295
Green	.348
Blue	.438

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a low to fair relationship exists between reaction time and wall volley scores. The results displayed in Table 5 seem to be in agreement with the conclusions of Burg and Hulbert (1961) who found that a low correlation of .394 existed between static visual acuity and dynamic visual acuity. In a later study, Burg (1966) stated that "performance on a dynamic acuity test may be more closely correlated with task performance than is the score obtained on a test of static (or standard) acuity" (p. 460). The conclusions of the present study support this theory. The third hypothesis which stated that there will be no significant relationship between reaction time, as measured by the light bulb test, and racquetball volleying scores was therefore accepted.

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Chapter V

Summary, Conclusions, and Recommendations

Summary

The purpose of this study was to determine if any of four selected colors would produce the fastest reaction time and if any of the four selected colors would produce a better performance on a racquetball wall volley test.

Twenty-three undergraduate students at Middle Tennessee State University served as subjects for the investigation. All subjects were officially enrolled members of one of two beginning racquetball classes. Each subject was given a color-blind test and was found to possess normal color vision. After successfully passing the color-blind test, each subject took a reaction time test. Subjects then reacted to four different colored light bulbs that had a white foreground. The light bulb colors were (a) blue, (b) green, (c) fluorescent orange, and (d) fluorescent yellow. The entire reaction time test was given to one subject before moving on to another subject. A pretest sequential order was determined before testing began. Ten trials were given for each color for a total of 40 trials. All 10 trials were given for one color before moving on to another color. A control cord was used by the subjects to stop the timer using the forefinger of their dominant hand.

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A wall volley test was also given to determine if any of the selected colored racquetballs produced a better performance which was determined by the number of volleys during a 30-sec test. A pretest color preference question was asked of all subjects. The four racquetball colors were (a) blue, (b) green, (c) fluorescent orange, and (d) fluorescent yellow. Twenty-four racquetballs, six of each color, were supplied by Ektelon Corporation. Each subject was given two 30-sec trials for each color on the wall volley test. The best of the two trials was counted as the final score.

The first statistical procedure used was an analysis of variance on reaction time scores. The same procedure was then used on wall volley scores. This method was used to determine if there were significant differences among the scores. After the significant differences were found in both reaction time and wall volley scores, correlated _t_ tests were computed. This method shows where the significant differences occur in the scores.

The data was then evaluated using the Pearson Product-Moment Correlation. Intercorrelations were conducted on the following: (a) blue reaction time with blue wall volley, (b) green reaction time with green wall volley, (c) fluorescent orange reaction time with fluorescent orange wall volley, and (d) fluorescent yellow reaction time with fluorescent wall volley. This particular method shows if there is a relationship between the two variables.

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Conclusions

Based on the data collected and the statistical results, the following conclusions were made concerning the hypotheses:

Hypothesis 1. There will be no significant difference in the reaction times of the beginning racquetball class members when using selected colored light bulbs. This hypothesis was rejected.

Hypothesis 2. There will be no significant difference in the wall volley test results with regard to ball color. This hypothesis was rejected.

Hypothesis 3. There will be no significant relationship between reaction time, as measured by the bulb test, and racquetball volleying scores. This hypothesis was accepted.

The following conclusions can be drawn from this study:

1. Light, bright fluorescent colors (orange and yellow) are reacted to quicker than dark, dull colors (blue and green).

2. Blue is inferior to the other three colors used in this study for reaction time and wall volley performance.

3. A person's ability to discriminate a moving target cannot be predicted adequately from their static acuity.

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4. After analyzing the results of this study, the green colored racquetball appeared to be superior to the other colors. Green is highly recommended over the currently used blue ball.

5. The fluorescent orange ball produced significantly better scores than the blue ball and is also highly recommended.

Recommendations

The following are recommendations based on the findings of this study:

1. A similar investigation should be conducted using a greater number of subjects.

2. In this study the balls used were originally blue. They were then painted various colors very carefully by Ektelon Corporation. The desired pure color was not completely achieved. Therefore, it is recommended that in future studies the color be original rather than painted over the exterior. It is possible that different results could occur.

3. A similar study using highly skilled players might be worthy of investigation.

4. Although yellow did not prove to be significantly better than blue on the wall volley test, yellow had a mean score of over 1.5 volleys higher than blue and is perceived as being better than blue for racquetball play.

5. A static visual test, which could not adequately predict dynamic visual acuity, was used to measure reaction time.

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It is suggested that a dynamic visual acuity reaction time test be created.

6. This study could be a starting point for other studies concerned with color perception of spectators and officials.

7. It is recommended that a study be implemented to determine if a difference exists between male and female performance when using various colored racquetballs.

8. It is possible that other colors are better than the four selected for this study.

9. A study to determine if there is a best ball for beginners and if there is a best ball for advanced players might be worthy of investigation.

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APPENDIX A

TEST FORM: ISHIHARA'S TEST

FOR COLOR-BLINDNESS

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ISHIHARA'S TEST
FOR
COLOR-BLINDNESS

Name ______________________ Subject # ______________

Age ______________________ Date ______________

Plate Number	Response	Normal Person	Red-Green Deficiencies	Person with Total Color Blindness
1.	________	12	12	12
2.	________	8	3	x
3.	________	5	2	x
4.	________	29	70	x
5.	________	74	21	x
6.	________	7	x	x
7.	________	45	x	x
8.	________	2	x	x
9.	________	x	2	x
10.	________	16	x	x
11.	________	traceable	x	x

Source: Ishihara, S., Ishihara's Tests for Color Blindness. Tokyo: San-Ei Printing Company, LTD., 1972.

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APPENDIX B

PRE-TEST COLOR PREFERENCE

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PRE-TEST COLOR PREFERENCE

Subject #	Preferred Ball Color
1	Orange
2	Orange
3	Blue
4	Blue
5	Blue
6	Green
7	Green
8	Blue
9	Green
10	Yellow
11	Orange
12	Blue
13	Blue
14	Blue
15	Orange
16	Orange
17	Blue
18	Orange
19	Orange
20	Green
21	Blue
22	Orange
23	Green

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APPENDIX C

PREDETERMINED COLOR SEQUENCES

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PREDETERMINED COLOR SEQUENCES

Subject #				
1	Blue	Green	Yellow	Orange
2	Blue	Yellow	Green	Orange
3	Blue	Green	Orange	Yellow
4	Blue	Orange	Green	Yellow
5	Blue	Orange	Yellow	Green
6	Green	Blue	Yellow	Orange
7	Green	Blue	Orange	Yellow
8	Green	Yellow	Orange	Blue
9	Green	Orange	Blue	Yellow
10	Green	Orange	Yellow	Blue
11	Yellow	Blue	Green	Orange
12	Yellow	Blue	Orange	Green
13	Yellow	Green	Orange	Blue
14	Yellow	Orange	Blue	Green
15	Yellow	Orange	Green	Blue
16	Orange	Blue	Green	Yellow
17	Orange	Blue	Yellow	Green
18	Orange	Green	Blue	Yellow
19	Orange	Yellow	Blue	Green
20	Orange	Yellow	Green	Blue
21	Blue	Green	Yellow	Orange
22	Blue	Yellow	Green	Orange
23	Blue	Yellow	Orange	Green

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APPENDIX D

RAW DATA FOR WALL VOLLEY

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RAW DATA FOR WALL VOLLEY

Subject #	Blue First	Blue Second	Blue Best	Green First	Green Second	Green Best
1	21	27	27	28	25	28
2	26	22	26	26	32	32
3	24	22	24	26	26	26
4	28	32	32	32	31	32
5	34	35	35	49	45	49
6	16	17	17	18	18	18
7	28	28	28	27	35	35
8	23	27	27	20	26	26
9	18	23	23	20	18	20
10	25	29	29	23	23	23
11	26	29	29	29	28	29
12	25	27	27	36	31	36
13	25	30	30	23	30	30
14	30	26	30	33	30	33
15	31	30	31	35	41	41
16	17	17	17	22	26	26
17	16	20	20	29	24	29
18	21	26	26	21	27	27
19	23	21	23	29	30	30
20	32	28	32	30	31	31
21	28	29	29	30	28	30
22	24	23	24	25	27	27
23	15	20	20	22	22	22

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RAW DATA FOR WALL VOLLEY

Subject	Orange			Yellow		
#	First	Second	Best	First	Second	Best
1	34	29	34	30	28	30
2	36	43	43	31	28	31
3	26	27	27	29	27	29
4	28	26	28	33	28	33
5	40	39	40	39	43	43
6	20	23	23	19	17	19
7	26	25	26	21	27	27
8	30	28	30	24	28	28
9	21	23	23	24	23	24
10	25	28	28	23	22	23
11	33	26	33	28	26	28
12	28	32	32	25	19	25
13	37	37	37	22	33	33
14	25	28	28	25	27	27
15	31	24	31	25	24	25
16	16	17	17	20	25	25
17	23	20	23	29	25	29
18	21	18	21	25	25	25
19	18	23	23	20	29	29
20	28	26	28	24	24	24
21	24	28	28	31	33	33
22	29	27	29	27	22	27
23	23	24	24	27	24	27

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APPENDIX E

SUMMARY OF WALL VOLLEY DATA

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SUMMARY OF WALL VOLLEY DATA

Best of Two Trials

Subject #	Blue	Green	Orange	Yellow
1	27	28	34	30
2	26	32	43	31
3	24	26	27	29
4	32	32	28	33
5	35	49	40	43
6	17	18	23	29
7	28	35	26	27
8	27	26	30	28
9	23	20	23	24
10	29	23	28	23
11	29	29	33	28
12	27	36	32	25
13	30	30	37	33
14	30	33	28	27
15	31	41	31	25
16	17	26	17	25
17	20	29	23	29
18	26	27	21	25
19	23	30	23	29
20	32	31	28	24
21	29	30	28	33

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SUMMARY OF WALL VOLLEY DATA

continued

Subject #	Blue	Green	Orange	Yellow
22	24	27	29	27
23	20	22	24	27
Total =	606	680	656	644
Mean =	26.347	29.565	28.521	28.000

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APPENDIX F

RAW DATA FOR REACTION TIME

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RAW DATA FOR REACTION TIME

Subject # 1

Trial #	Blue	Green	Yellow	Orange
1	.29	.34	.22	.24
2	.22	.29	.28	.27
3	.27	.29	.28	.26
4	.29	.26	.32	.25
5	.29	.29	.26	.28
6	.27	.30	.33	.28
7	.29	.29	.27	.26
8	.25	.25	.29	.30
9	.29	.25	.27	.26
10	.24	.29	.29	.26
Mean =	.270	.285	.281	.266

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RAW DATA FOR REACTION TIME

Subject # 2

Trial #	Blue	Yellow	Green	Orange
1	.22	.21	.21	.22
2	.20	.18	.20	.22
3	.21	.18	.21	.21
4	.24	.20	.23	.24
5	.15	.17	.22	.22
6	.21	.21	.21	.24
7	.17	.23	.17	.22
8	.17	.20	.19	.21
9	.20	.20	.24	.20
10	.21	.21	.24	.24
Mean =	.198	.199	.212	.222

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RAW DATA FOR REACTION TIME

Subject # 3

Trial #	Blue	Green	Orange	Yellow
1	.26	.28	.23	.25
2	.21	.22	.25	.23
3	.26	.23	.26	.23
4	.26	.36	.26	.18
5	.22	.22	.23	.19
6	.26	.22	.30	.29
7	.28	.21	.19	.22
8	.22	.24	.21	.22
9	.25	.27	.21	.23
10	.29	.22	.23	.28
Mean =	.251	.247	.237	.232

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RAW DATA FOR REACTION TIME

Subject # 4

Trial #	Blue	Orange	Green	Yellow
1	.23	.22	.21	.22
2	.26	.24	.22	.26
3	.22	.20	.25	.24
4	.35	.26	.25	.28
5	.25	.23	.26	.25
6	.27	.29	.28	.24
7	.23	.20	.24	.22
8	.24	.23	.21	.26
9	.22	.22	.23	.24
10	.25	.22	.25	.25
Mean =	.252	.231	.240	.246

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RAW DATA FOR REACTION TIME

Subject # 5

Trial #	Blue	Orange	Yellow	Green
1	.23	.22	.23	.24
2	.17	.23	.23	.21
3	.24	.22	.21	.19
4	.24	.24	.23	.24
5	.26	.17	.21	.20
6	.25	.26	.23	.25
7	.21	.23	.27	.22
8	.21	.20	.16	.23
9	.21	.22	.21	.17
10	.23	.23	.22	.21
Mean =	.225	.222	.220	.216

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RAW DATA FOR REACTION TIME

Subject # 6

Trial #	Green	Blue	Yellow	Orange
1	.24	.24	.24	.25
2	.21	.26	.23	.27
3	.23	.25	.26	.29
4	.23	.28	.22	.21
5	.25	.28	.26	.25
6	.24	.29	.30	.26
7	.24	.28	.23	.28
8	.24	.26	.25	.24
9	.20	.24	.23	.25
10	.25	.26	.29	.25
Mean =	.233	.264	.251	.255

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RAW DATA FOR REACTION TIME

Subject # 7

Trial #	Green	Blue	Orange	Yellow
1	.32	.17	.24	.16
2	.22	.22	.22	.21
3	.26	.23	.17	.29
4	.26	.28	.23	.24
5	.22	.23	.19	.16
6	.27	.24	.27	.29
7	.22	.22	.19	.25
8	.22	.26	.23	.20
9	.33	.20	.15	.25
10	.25	.26	.17	.26
Mean =	.257	.231	.206	.231

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RAW DATA FOR REACTION TIME

Subject # 8

Trial #	Green	Yellow	Orange	Blue
1	.28	.24	.27	.27
2	.25	.22	.25	.25
3	.25	.26	.27	.28
4	.26	.23	.24	.24
5	.28	.24	.24	.25
6	.25	.25	.26	.30
7	.31	.27	.26	.21
8	.25	.24	.19	.24
9	.26	.24	.24	.24
10	.27	.26	.24	.25
Mean =	.266	.245	.246	.253

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RAW DATA FOR REACTION TIME

Subject # 9

Trial #	Green	Orange	Blue	Yellow
1	.35	.24	.23	.27
2	.24	.28	.30	.26
3	.24	.25	.23	.25
4	.32	.26	.31	.29
5	.28	.25	.26	.23
6	.28	.29	.31	.31
7	.22	.27	.28	.24
8	.27	.26	.28	.26
9	.24	.24	.25	.23
10	.30	.31	.29	.40
Mean =	.274	.265	.274	.274

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RAW DATA FOR REACTION TIME

Subject # 10

Trial #	Green	Orange	Yellow	Blue
1	.25	.23	.23	.23
2	.26	.21	.22	.24
3	.26	.26	.22	.25
4	.24	.27	.25	.24
5	.23	.24	.21	.21
6	.24	.23	.24	.27
7	.21	.21	.21	.23
8	.25	.23	.24	.26
9	.23	.23	.22	.27
10	.24	.22	.22	.24
Mean =	.241	.233	.226	.244

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RAW DATA FOR REACTION TIME

Subject # 11

Trial #	Yellow	Blue	Green	Orange
1	.23	.23	.22	.22
2	.21	.30	.22	.24
3	.21	.22	.23	.20
4	.24	.20	.26	.24
5	.21	.20	.26	.21
6	.25	.23	.27	.26
7	.22	.20	.24	.18
8	.20	.22	.23	.22
9	.20	.28	.24	.21
10	.19	.24	.25	.20
Mean =	.216	.232	.242	.218

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RAW DATA FOR REACTION TIME

Subject # 12

Trial #	Yellow	Blue	Orange	Green
1	.29	.28	.28	.32
2	.25	.28	.23	.27
3	.26	.26	.23	.28
4	.29	.28	.25	.30
5	.27	.24	.25	.27
6	.28	.27	.24	.25
7	.25	.28	.26	.26
8	.23	.26	.25	.19
9	.33	.27	.26	.25
10	.28	.31	.25	.27
Mean =	.273	.273	.250	.266

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RAW DATA FOR REACTION TIME

Subject # 13

Trial #	Yellow	Green	Orange	Blue
1	.25	.24	.25	.26
2	.23	.25	.25	.26
3	.23	.27	.25	.25
4	.23	.24	.27	.25
5	.21	.22	.19	.25
6	.26	.25	.25	.29
7	.24	.28	.29	.23
8	.22	.25	.25	.22
9	.21	.23	.24	.24
10	.23	.27	.24	.25
Mean =	.231	.250	.248	.250

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RAW DATA FOR REACTION TIME

Subject # 14

Trial #	Yellow	Orange	Blue	Green
1	.21	.25	.23	.21
2	.21	.24	.26	.25
3	.32	.24	.22	.23
4	.24	.23	.24	.26
5	.21	.22	.24	.28
6	.21	.23	.30	.25
7	.22	.19	.22	.23
8	.19	.23	.24	.23
9	.22	.23	.23	.22
10	.28	.28	.24	.21
Mean =	.231	.234	.242	.237

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RAW DATA FOR REACTION TIME

Subject # 15

Trial #	Yellow	Orange	Green	Blue
1	.29	.30	.29	.31
2	.25	.28	.27	.28
3	.29	.27	.27	.27
4	.27	.30	.33	.29
5	.24	.26	.25	.26
6	.30	.33	.31	.33
7	.25	.26	.28	.24
8	.25	.27	.23	.26
9	.24	.28	.27	.29
10	.27	.25	.28	.30
Mean =	.265	.280	.278	.283

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RAW DATA FOR REACTION TIME

Subject # 16

Trial #	Orange	Blue	Green	Yellow
1	.38	.22	.21	.19
2	.24	.22	.22	.20
3	.19	.20	.16	.19
4	.24	.25	.26	.24
5	.22	.22	.21	.16
6	.23	.28	.24	.22
7	.16	.26	.16	.17
8	.19	.21	.19	.17
9	.22	.17	.18	.16
10	.19	.35	.25	.22
Mean =	.226	.238	.208	.192

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RAW DATA FOR REACTION TIME

Subject # 17

Trial #	Orange	Blue	Yellow	Green
1	.31	.26	.24	.28
2	.21	.22	.22	.26
3	.24	.24	.23	.23
4	.24	.25	.23	.26
5	.25	.29	.21	.23
6	.24	.24	.23	.23
7	.22	.23	.21	.21
8	.21	.23	.25	.25
9	.29	.27	.21	.25
10	.26	.22	.22	.28
Mean =	.247	.245	.225	.248

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RAW DATA FOR REACTION TIME

Subject # 18

Trial #	Orange	Green	Blue	Yellow
1	.25	.26	.24	.23
2	.26	.28	.28	.26
3	.25	.27	.25	.24
4	.29	.30	.30	.26
5	.25	.26	.27	.28
6	.26	.30	.31	.28
7	.26	.24	.26	.25
8	.27	.26	.37	.25
9	.25	.26	.27	.26
10	.27	.28	.28	.26
Mean =	.261	.271	.283	.257

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RAW DATA FOR REACTION TIME

Subject # 19

Trial #	Orange	Yellow	Blue	Green
1	.22	.22	.22	.14
2	.22	.20	.19	.22
3	.22	.15	.20	.16
4	.26	.21	.25	.22
5	.22	.18	.18	.21
6	.25	.25	.26	.23
7	.23	.19	.18	.20
8	.19	.19	.19	.22
9	.22	.22	.21	.20
10	.26	.20	.25	.23
Mean =	.229	.201	.213	.203

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RAW DATA FOR REACTION TIME

Subject # 20

Trial #	Orange	Yellow	Green	Blue
1	.22	.19	.24	.23
2	.21	.21	.22	.22
3	.27	.21	.24	.22
4	.26	.21	.25	.24
5	.23	.23	.25	.23
6	.24	.23	.22	.24
7	.23	.21	.23	.23
8	.21	.22	.23	.23
9	.22	.23	.22	.25
10	.22	.21	.24	.24
Mean =	.231	.215	.234	.233

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RAW DATA FOR REACTION TIME

Subject # 21

Trial #	Blue	Green	Yellow	Orange
1	.24	.24	.23	.24
2	.24	.25	.25	.21
3	.25	.22	.22	.25
4	.26	.23	.28	.28
5	.22	.20	.21	.23
6	.34	.33	.23	.25
7	.21	.22	.22	.20
8	.22	.18	.18	.21
9	.23	.21	.21	.21
10	.26	.24	.25	.26
Mean =	.247	.232	.228	.234

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RAW DATA FOR REACTION TIME

Subject # 22

Trial #	Blue	Yellow	Green	Orange
1	.22	.20	.22	.22
2	.29	.22	.27	.23
3	.21	.22	.22	.25
4	.26	.23	.26	.28
5	.22	.21	.30	.28
6	.27	.28	.29	.28
7	.22	.25	.24	.22
8	.23	.26	.25	.21
9	.26	.22	.24	.20
10	.25	.23	.26	.26
Mean =	.243	.232	.255	.243

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RAW DATA FOR REACTION TIME

Subject # 23

Trial #	Blue	Yellow	Orange	Green
1	.29	.24	.22	.26
2	.21	.24	.21	.22
3	.24	.22	.25	.22
4	.23	.22	.24	.23
5	.19	.20	.27	.26
6	.29	.26	.23	.25
7	.23	.19	.24	.23
8	.23	.20	.20	.21
9	.24	.22	.26	.22
10	.20	.19	.24	.25
Mean =	.235	.218	.236	.235

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APPENDIX G

SUMMARY OF REACTION TIME DATA

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SUMMARY OF REACTION TIME DATA

Subject #	Blue	Green	Orange	Yellow
1	.270	.285	.266	.281
2	.198	.212	.222	.199
3	.251	.247	.237	.232
4	.252	.240	.231	.246
5	.225	.216	.222	.220
6	.264	.233	.255	.251
7	.231	.257	.206	.231
8	.253	.266	.246	.245
9	.274	.274	.265	.274
10	.244	.241	.233	.226
11	.232	.242	.218	.216
12	.273	.266	.250	.273
13	.250	.250	.248	.231
14	.242	.237	.234	.231
15	.283	.278	.280	.265
16	.238	.208	.226	.192
17	.245	.248	.247	.225
18	.283	.271	.261	.257
19	.213	.203	.229	.201
20	.233	.234	.231	.215
21	.247	.232	.234	.228

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SUMMARY OF REACTION TIME DATA

Subject #	Blue	Green	Orange	Yellow
22	.243	.255	.243	.232
23	.235	.235	.236	.218
Total =	5.679	5.630	5.520	5.389
Mean =	.2469	.2447	.2400	.2343

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APPENDIX H

CORRELATED t-TEST COMPUTATIONS

FOR REACTION TIME

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CORRELATED t-TEST - BLUE AND GREEN REACTION TIME

Subject	Blue	Green	D	D^2
1	.270	.285	-.015	.000225
2	.198	.212	-.014	.000196
3	.251	.247	.004	.000016
4	.252	.240	.012	.000144
5	.225	.216	.009	.000081
6	.264	.233	.031	.000961
7	.231	.257	-.026	.000676
8	.253	.266	-.013	.000169
9	.274	.274	.000	.000000
10	.244	.241	.003	.000009
11	.232	.242	-.010	.000100
12	.273	.266	.007	.000049
13	.250	.250	.000	.000000
14	.242	.237	.005	.000025
15	.283	.278	.005	.000025
16	.238	.208	.030	.000900
17	.245	.248	-.003	.000009
18	.283	.271	.012	.000144
19	.213	.203	-.010	.000100
20	.233	.234	-.001	.000001
21	.247	.232	.015	.000225
22	.243	.255	-.012	.000144
23	.235	.235	.000	.000000

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CORRELATED t-TEST - BLUE AND GREEN REACTION TIME

(CONTINUED)

Sum =	5.679	5.630	.049	.004199

$$\underline{t} = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$\underline{t} = \frac{.049}{\sqrt{23 \times .004199 - (.049)^2 / 23 - 1}}$$

$$\underline{t} = \frac{.049}{\sqrt{.094176 - .002401 / 22}}$$

$$\underline{t} = \frac{.049}{\sqrt{.094176 / 22}}$$

$$\underline{t} = \frac{.049}{\sqrt{.00428073}}$$

$$\underline{t} = \frac{.049}{.06542727}$$

$$\underline{t} = .74892319$$

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CORRELATED t-TEST - BLUE AND FLUORESCENT ORANGE REACTION TIME

Subject	Blue	Fluorescent Orange	D	D^2
1	.270	.266	.004	.000016
2	.198	.222	-.024	.000576
3	.251	.237	.014	.000196
4	.252	.231	.021	.000441
5	.225	.222	.003	.000009
6	.264	.255	.009	.000081
7	.231	.206	.025	.000625
8	.253	.246	.007	.000049
9	.274	.265	.009	.000081
10	.244	.233	.011	.000121
11	.232	.218	.014	.000196
12	.273	.250	.023	.000529
13	.250	.248	.002	.000004
14	.242	.234	.008	.000064
15	.283	.280	.003	.000009
16	.238	.226	.012	.000144
17	.245	.247	-.002	.000004
18	.283	.261	.022	.000484
19	.213	.229	-.016	.000256
20	.233	.231	.002	.000004
21	.247	.234	.013	.000169
22	.243	.243	.000	.000000
23	.235	.236	-.001	.000001

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CORRELATED t-TEST - BLUE AND FLUORESCENT ORANGE REACTION TIME

(CONTINUED)

Sum =	5.679	5.520	.159	.004059

$$\underline{t} = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$\underline{t} = \frac{.159}{\sqrt{23 \times .004059 - (.159)^2 / 23 - 1}}$$

$$\underline{t} = \frac{.159}{\sqrt{.093357 - .025281 / 22}}$$

$$\underline{t} = \frac{.159}{\sqrt{.068076 / 22}}$$

$$\underline{t} = \frac{.159}{\sqrt{.00309436}}$$

$$\underline{t} = \frac{.159}{.055627}$$

$\underline{t}$ = 2.8583242

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CORRELATED t-TEST - BLUE AND FLUORESCENT YELLOW REACTION TIME

Subject	Blue	Fluorescent Yellow	D	D^2
1	.270	.281	-.011	.000121
2	.198	.199	-.001	.000001
3	.251	.232	.019	.000361
4	.252	.246	.006	.000036
5	.225	.220	.005	.000025
6	.264	.251	.013	.000169
7	.231	.231	.000	.000000
8	.253	.245	.008	.000064
9	.274	.274	.000	.000000
10	.244	.226	.018	.000324
11	.232	.216	.016	.000256
12	.273	.273	.000	.000000
13	.250	.231	.019	.000361
14	.242	.231	.011	.000121
15	.283	.265	.018	.000324
16	.238	.192	.046	.002116
17	.245	.225	.020	.000400
18	.283	.257	.026	.000676
19	.213	.201	.012	.000144
20	.233	.215	.018	.000324
21	.247	.228	.019	.000361
22	.243	.232	.011	.000121
23	.235	.218	.017	.000289

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CORRELATED t-TEST - BLUE AND FLUORESCENT YELLOW REACTION TIME

(CONTINUED)

Sum =	5.679	5.389	.290	.006594

$$t = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$t = \frac{.290}{\sqrt{23 \times .006594 - (.290)^2 \;/\; 23 - 1}}$$

$$t = \frac{.290}{\sqrt{.151662 - .0841 \;/\; 22}}$$

$$t = \frac{.290}{\sqrt{.067562 \;/\; 22}}$$

$$t = \frac{.290}{\sqrt{.003071}}$$

$$t = \frac{.290}{.0554166}$$

$$t = 5.233089$$

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CORRELATED t-TEST - GREEN AND FLUORESCENT ORANGE REACTION TIME

Subject	Green	Fluorescent Orange	D	D^2
1	.285	.266	.019	.000361
2	.212	.222	-.010	.000100
3	.247	.237	.010	.000100
4	.240	.231	.009	.000081
5	.216	.222	-.006	.000036
6	.233	.255	-.022	.000484
7	.257	.206	.051	.002601
8	.266	.246	.020	.000400
9	.274	.265	.009	.000081
10	.241	.233	.008	.000064
11	.242	.218	.024	.000576
12	.266	.250	.016	.000256
13	.250	.248	.002	.000004
14	.237	.234	.003	.000009
15	.278	.280	-.002	.000004
16	.208	.226	-.018	.000324
17	.248	.247	.001	.000001
18	.271	.261	.010	.000100
19	.203	.229	-.026	.000676
20	.234	.231	.003	.000009
21	.232	.234	-.002	.000004
22	.255	.243	.012	.000144
23	.235	.236	-.001	.000001

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CORRELATED t-TEST - GREEN AND FLUORESCENT ORANGE REACTION TIME

(CONTINUED)

Sum =	5.630	5.520	.110	.006416

$$\underline{t} = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$\underline{t} = \frac{.110}{\sqrt{23 \times .006416 - (.110)^2 / 23 - 1}}$$

$$\underline{t} = \frac{.110}{\sqrt{.147568 - .0121 / 22}}$$

$$\underline{t} = \frac{.110}{\sqrt{.135468 / 22}}$$

$$\underline{t} = \frac{.110}{\sqrt{.00615764}}$$

$$\underline{t} = \frac{.110}{.07847063}$$

$$\underline{t} = 1.4017984$$

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CORRELATED *t*-TEST - GREEN AND FLUORESCENT YELLOW REACTION TIME

Subject	Green	Fluorescent Yellow	D	D^2
1	.285	.281	.004	.000016
2	.212	.199	.013	.000169
3	.247	.232	.015	.000225
4	.240	.246	-.006	.000036
5	.216	.220	-.004	.000016
6	.233	.251	-.018	.000324
7	.257	.231	.026	.000676
8	.266	.245	.021	.000441
9	.274	.274	.000	.000000
10	.241	.226	.015	.000225
11	.242	.216	.026	.000676
12	.266	.273	-.007	.000049
13	.250	.231	.019	.000361
14	.237	.231	.006	.000036
15	.278	.265	.013	.000169
16	.208	.192	.016	.000256
17	.248	.225	.023	.000529
18	.271	.257	.014	.000196
19	.203	.201	.002	.000004
20	.234	.215	.019	.000361
21	.232	.228	.004	.000016
22	.255	.232	.023	.000529
23	.235	.218	.017	.000289

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CORRELATED $\underline{t}$-TEST - GREEN AND FLUORESCENT YELLOW REACTION TIME

(CONTINUED)

Sum =	5.630	5.389	.241	.005599

$$\underline{t} = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$\underline{t} = \frac{.241}{\sqrt{23 \times .005599 - (.241)^2 / 23 - 1}}$$

$$\underline{t} = \frac{.241}{\sqrt{.128777 - .058081 / 22}}$$

$$\underline{t} = \frac{.241}{\sqrt{.070696 / 22}}$$

$$\underline{t} = \frac{.241}{\sqrt{.00321345}}$$

$$\underline{t} = \frac{.241}{.05668734}$$

$$\underline{t} = 4.2513902$$

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CORRELATED *t*-TEST - FLUORESCENT ORANGE AND FLUORESCENT YELLOW REACTION TIME

Subject	Fluorescent Orange	Fluorescent Yellow	D	D^2
1	.266	.281	-.015	.000225
2	.222	.199	.023	.000529
3	.237	.232	.005	.000025
4	.231	.246	-.015	.000225
5	.222	.220	.002	.000004
6	.255	.251	.004	.000016
7	.206	.231	-.025	.000625
8	.246	.245	.001	.000001
9	.265	.274	-.009	.000081
10	.233	.226	.007	.000049
11	.218	.216	.002	.000004
12	.250	.273	-.023	.000529
13	.248	.231	.017	.000289
14	.234	.231	.003	.000009
15	.280	.265	.015	.000225
16	.226	.192	.034	.001156
17	.247	.225	.022	.000484
18	.261	.257	.004	.000016
19	.229	.201	.028	.000784
20	.231	.215	.016	.000256
21	.234	.228	.006	.000036
22	.243	.232	.011	.000121
23	.236	.218	.018	.000324

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CORRELATED t-TEST - FLUORESCENT ORANGE AND FLUORESCENT YELLOW REACTION TIME (CONTINUED)

Sum =	5.520	5.389	.131	.006013

$$\underline{t} = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$\underline{t} = \frac{.131}{\sqrt{23 \times .006013 - (.131)^2 \ / \ 23 - 1}}$$

$$\underline{t} = \frac{.131}{\sqrt{.138299 - .017161 \ / \ 22}}$$

$$\underline{t} = \frac{.131}{\sqrt{.121138 \ / \ 22}}$$

$$\underline{t} = \frac{.131}{\sqrt{.00550627}}$$

$$\underline{t} = \frac{.131}{.07420426}$$

$$\underline{t} = 1.7653973$$

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APPENDIX I

CORRELATED t-TEST COMPUTATIONS

FOR WALL VOLLEY

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CORRELATED t-TEST - BLUE AND GREEN WALL VOLLEY

Subject	Blue	Green	D	D^2
1	27	28	-1	1
2	26	32	-6	36
3	24	26	-2	4
4	32	32	0	0
5	35	49	-14	196
6	17	18	-1	1
7	28	35	-7	49
8	27	26	1	1
9	23	20	3	9
10	29	23	6	36
11	29	29	0	0
12	27	36	-9	81
13	30	30	0	0
14	30	33	-3	9
15	31	41	-10	100
16	17	26	-9	81
17	20	29	-9	81
18	26	27	-1	1
19	23	30	-7	49
20	32	31	1	1
21	29	30	-1	1
22	24	27	-3	9
23	20	22	-2	4

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CORRELATED t-TEST - BLUE AND GREEN

(CONTINUED)

Sum =	606	680	-74	750

$$\underline{t} = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$\underline{t} = \frac{-74}{\sqrt{23 \times 750 - (-74)^2 \quad / 23-1}}$$

$$\underline{t} = \frac{-74}{\sqrt{17250 - 5476 / 22}}$$

$$\underline{t} = \frac{-74}{\sqrt{11774 / 22}}$$

$$\underline{t} = \frac{-74}{\sqrt{535.1818}}$$

$$\underline{t} = \frac{-74}{23.1340}$$

$$\underline{t} = -3.1988$$

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CORRELATED t-TEST - BLUE AND FLUORESCENT

ORANGE WALL VOLLEY

Subject	Blue	Orange	D	D^2
1	27	34	-7	49
2	26	43	-17	289
3	24	27	-3	9
4	32	28	4	16
5	35	40	-5	25
6	17	23	-6	36
7	28	26	2	4
8	27	30	-3	9
9	23	23	0	0
10	29	28	1	1
11	29	33	-4	16
12	27	32	-5	25
13	30	37	-7	49
14	30	28	2	4
15	31	31	0	0
16	17	17	0	0
17	20	23	-3	9
18	26	21	5	25
19	23	23	0	0
20	32	28	4	16
21	29	28	1	1
22	24	29	-5	25
23	20	24	-4	16

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CORRELATED $\underline{t}$-TEST - BLUE AND FLUORESCENT

ORANGE WALL VOLLEY

(CONTINUED)

Sum =	606	656	-50	624

$$\underline{t} = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$\underline{t} = \frac{-50}{\sqrt{23 \text{ x } 624 - (-50)^2 \quad / \quad 23 - 1}}$$

$$\underline{t} = \frac{-50}{\sqrt{14352 - 2500 / 22}}$$

$$\underline{t} = \frac{-50}{\sqrt{11852 / 22}}$$

$$\underline{t} = \frac{-50}{\sqrt{538.72727}}$$

$$\underline{t} = \frac{-50}{23.210499}$$

$\underline{t}$ = -2.1541975

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CORRELATED t-TEST - BLUE AND FLUORESCENT

YELLOW WALL VOLLEY

Subject	Blue	Fluorescent Yellow	D	D^2
1	27	30	-3	9
2	26	31	-5	25
3	24	29	-5	25
4	32	33	-1	1
5	35	43	-8	64
6	17	19	-2	4
7	28	27	1	1
8	27	28	-1	1
9	23	24	-1	1
10	29	23	6	36
11	29	28	1	1
12	27	25	2	4
13	30	33	-3	9
14	30	27	3	9
15	31	25	6	36
16	17	25	-8	64
17	20	29	-9	81
18	26	25	1	1
19	23	29	-6	36
20	32	24	8	64
21	29	33	-4	16
22	24	27	-3	9
23	20	27	-7	49

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CORRELATED t-TEST- BLUE AND

FLUORESCENT YELLOW WALL VOLLEY

(CONTINUED)

Sum =	606	644	-38	546

$$\underline{t} = \frac{\Sigma D}{\sqrt{[N\Sigma D^2 - (\Sigma D)^2] / (N-1)}}$$

$$\underline{t} = \frac{-38}{\sqrt{23 \times 546 - (-38)^2 / 23-1}}$$

$$\underline{t} = \frac{-38}{\sqrt{12558 - 1444 / 22}}$$

$$\underline{t} = \frac{-38}{\sqrt{11114 / 22}}$$

$$\underline{t} = \frac{-38}{\sqrt{505.18182}}$$

$$\underline{t} = \frac{-38}{22.47625}$$

$$\underline{t} = -1.6906735$$

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CORRELATED t-TEST - GREEN AND FLUORESCENT ORANGE WALL VOLLEY

Subject	Green	Fluorescent Orange	D	D^2
1	28	34	-6	36
2	32	43	-11	121
3	26	27	-1	1
4	32	28	4	16
5	49	40	9	81
6	18	23	-5	25
7	35	26	9	81
8	26	30	-4	16
9	20	23	-3	9
10	23	28	-5	25
11	29	33	-4	16
12	36	32	4	16
13	30	37	-7	49
14	33	28	5	25
15	41	31	10	100
16	26	17	9	81
17	29	23	6	36
18	27	21	6	36
19	30	23	7	49
20	31	28	3	9
21	30	28	2	4
22	27	29	-2	4
23	22	24	-2	4

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CORRELATED t-TEST - GREEN AND FLUORESCENT

ORANGE WALL VOLLEY

(CONTINUED)

Sum =	680	656	24	830

$$\underline{t} = \frac{\Sigma D}{\sqrt{[N\Sigma D^2 - (\Sigma D)^2] / (N-1)}}$$

$$\underline{t} = \frac{24}{\sqrt{23 \times 830 - (24)^2 / 23-1}}$$

$$\underline{t} = \frac{24}{\sqrt{19090 - 576 / 22}}$$

$$\underline{t} = \frac{24}{\sqrt{18514 / 22}}$$

$$\underline{t} = \frac{24}{\sqrt{841.54545}}$$

$$\underline{t} = \frac{24}{29.009403}$$

$$\underline{t} = .82731796$$

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CORRELATED t-TEST - GREEN AND FLUORESCENT YELLOW WALL VOLLEY

Subject	Green	Fluorescent Yellow	D	D^2
1	28	30	-2	4
2	32	31	1	1
3	26	29	-3	9
4	32	33	-1	1
5	49	43	6	36
6	18	19	-1	1
7	35	27	8	64
8	26	28	-2	4
9	20	24	-4	16
10	23	23	0	0
11	29	28	1	1
12	36	25	11	121
13	30	33	-3	9
14	33	27	6	36
15	41	25	36	256
16	26	25	1	1
17	29	29	0	0
18	27	25	2	4
19	30	29	1	1
20	31	24	7	49
21	30	33	-3	9
22	27	27	0	0
23	22	27	-5	25

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CORRELATED t-TEST - GREEN AND FLUORESCENT

YELLOW WALL VOLLEY

(CONTINUED)

Sum =	680	644	36	648

$$t = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$t = \frac{36}{\sqrt{23 \times 648 - (36)^2 / 23 - 1}}$$

$$t = \frac{36}{\sqrt{14904 - 1296 / 22}}$$

$$t = \frac{36}{\sqrt{13608 / 22}}$$

$$t = \frac{36}{\sqrt{618.54545}}$$

$$t = \frac{36}{24.870574}$$

$$t = 1.4474937$$

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CORRELATED t-TEST - FLUORESCENT ORANGE AND FLUORESCENT YELLOW WALL VOLLEY

Subject	Fluorescent Orange	Fluorescent Yellow	D	D^2
1	34	30	4	16
2	43	31	12	144
3	27	29	-2	4
4	28	33	-5	25
5	40	43	-3	9
6	23	19	4	16
7	26	27	-1	1
8	30	28	2	4
9	23	24	-1	1
10	28	23	5	25
11	33	28	5	25
12	32	25	7	49
13	37	33	4	16
14	28	27	1	1
15	31	25	6	36
16	17	25	-8	64
17	23	29	-6	36
18	21	25	-4	16
19	23	29	-6	36
20	28	24	4	16
21	28	33	-5	25
22	29	27	2	4
23	24	27	-3	9

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CORRELATED t-TEST - FLUORESCENT ORANGE AND FLUORESCENT YELLOW WALL VOLLEY

(CONTINUED)

Sum =	656	644	12	574

$$\underline{t} = \frac{\Sigma D}{\sqrt{\left[N\Sigma D^2 - (\Sigma D)^2\right] / (N-1)}}$$

$$\underline{t} = \frac{12}{\sqrt{23 \times 578 - (12)^2 \ / \ 22}}$$

$$\underline{t} = \frac{12}{\sqrt{13294 - 144 / 22}}$$

$$\underline{t} = \frac{12}{\sqrt{13150 / 22}}$$

$$\underline{t} = \frac{12}{\sqrt{597.72727}}$$

$$\underline{t} = \frac{12}{24.448462}$$

$$\underline{t} = .49082842$$

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