THE EFFECTS OF BLUE, RED, AND WHITE LIGHTING ON SELECTED PHYSIOLOGICAL FACTORS AND MOTOR PERFORMANCE OF SKILLED AND HIGHLY SKILLED RACQUETBALL PLAYERS

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ABSTRACT

THE EFFECTS OF BLUE, RED, AND WHITE LIGHTING ON SELECTED PHYSIOLOGICAL FACTORS AND MOTOR PERFORMANCE OF SKILLED AND HIGHLY SKILLED RACQUETBALL PLAYERS. (MAY 1982)

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The purpose of this investigation was to determine the effects of colored lighting conditions (blue, red, and white) on the variables of blood pressure, heart rate, and temperature in the performance of two groups of racquetball players. A secondary purpose was to determine if the performance of Group 1 (highly skilled) and the performance of Group 2 (skilled) racquetball players differed significantly under the color conditions of blue, red, and white lights. Additionally, the study examined the emotional perceptions of racquetball players relative to their performance under blue, red, and white lighting conditions. The groups were tested utilizing a recognized racquetball wall volley test under various colored lighting conditions. The test involved volleying a ball against the front wall of the test court for two, 30-second trials; once from behind the short line and once from 12 feet behind the short line. Prior to the wall volley test, each subject was seated in the colored court condition for two minutes. Pre-test and post-test readings for blood pressure, heart rate, and temperature were measured for each subject under each color condition. At the end of each testing session, the subjects completed a mini-questionnaire concerned with feelings and reactions to the colored lighting condition that had just been completed. In addition, a comprehensive questionnaire at the completion of all the tests was also filled out by the subjects. Statistical analysis indicated that there was no significance between the effects of color conditions (blue, red, and white) and blood pressure, heart rate, and temperature in Group 1 (highly skilled) and in Group 2 (skilled) racquetball players. Analysis of data indicated that there was no significance between the effects of the color conditions (blue, red, and white) on the performance of the highly skilled and skilled players. A significance of $F(1,17) = 8.29$ $p < .05$ was found between the highly skilled and skilled racquetball players' performance. The responses the the mini-questionnaire and questionnaire indicated that a majority of the subjects felt uncomfortable under the red lighting condition and warmer under this color environment. The blue lighting created a cooler environment among the subjects. Within the scope and limitations of the study, the investigator concluded that colored environments have no substantial effect on diastolic or systolic blood pressure, heart rate, temperature and performance. Further, both highly skilled and skilled participants were not substantially affected by various colored environments.

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Chapter 1

INTRODUCTION

Man, for centuries, has been concerned with illumination and the effects it has on human emotions and performance. The majority of studies performed have concluded that color does have a noticeable effect on man's psychological and physical well-being. Results such as these are responsible for institutions, businesses and schools providing a more desirable environment for employees and students. With more research in this area, the discovery of better surroundings could enhance and enable more efficient general and motor performance (Papadatos, 1964).

The relationship between color and its effect on behavior has been popular knowledge throughout ancient and modern history and over the majority of the inhabited world. The existence of such a connection between color and effect can be experienced readily by most individuals who are not insensitive to color. The effects of color on individuals have been indicated by a number of scientists, particularly in the fields of psychiatry and psychology, such as: Birren, Daniel, Luckish, and Podolsky, and all have realized the importance of color and the great factor it has on man (Schachtel, 1943).

Man at the dawn of civilization recognized the importance of sunlight and how essential it was in order to survive. Consequently, colors were worshiped because of their relationship with sunlight. For many years, various colors represented different myths and beliefs; however, it was not until the mid 1800's that particular studies were attempted in order to discover the true meanings and effects of colors and colored lighting on certain situations (Birren, 1961).

A great deal of research was completed concerning the emotional and physical effects of color on individuals (Birren, 1955, 1961, 1970;

Bross & Jackson, 1981; Plack & Shick, 1974; Spiegal & Keith-Spiegal, 1971). It was concluded that the exposure to a given specific color caused varying reactions from different individuals. This provided the background information that sparked numerous investigations and valuable findings (Bross & Jackson, 1981; Gerard, 1958; Plack, 1974; Shick, 1975).

Researchers have since accumulated an extensive body of knowledge and facts related to the effects of color on human behavior. Studies have been conducted in many areas of psychology and physiology indicating the impact that color has on performance. It is evident that there is a distinct relationship between color and human behavior, both psychologically and physiologically (Birren, 1961; Bross & Jackson, 1981; Gerard, 1958; Simon, 1971).

Psychologically, colors influence the reactions and performance of individuals and research has suggested that color may be perceived by the age of three months and continues to bring about different responses and reactions through life (Staples, 1938). It has been indicated that whether or not color preferences in man are innately determined or influenced by the environment, different colors have a definite psychological impact throughout the duration of one's life (Spiegal & Keith-Spiegal, 1971).

Investigators have also concluded that individuals associate certain colors with specific moods or emotional characteristics. The color red is associated with restlessness, agitation, aggressiveness, and passion and is also linked with being a warm or hot color. Blue, however, is described as being cool and is most often associated with tenderness, comfort, security, peace and calm (Birren, 1961).

Descriptive associations attributed to other colors are not as definite as associations for the colors of red and blue (Birren, 1961).

In agreement with these findings, other studies have shown that various colors can affect the feelings and moods of individuals. Colors and the utilization of certain colored lighting selections have been proven to have great psychological effects upon employees in industry (Birren, 1961); whereas, production was increased by 5 to 10%, absenteeism was reduced and employee morale was improved.

An additional area in which color has been investigated is the influence of various colors on pulse rate, blood pressure, rate of breathing, galvanic skin response, muscular activity, and psychomotor response (Birren, 1961; Bross & Jackson, 1981; Gerard, 1958; Papadatos, 1964; Pressy, 1921). These aforementioned areas along with body temperature, muscle relaxation and tension, and flexibility could all be improved when an individual is exposed to various lighting situations.

With the vast body of knowledge related to color effect on human behavior, it is unfortunate that in the area of sports and physical education very little research has been completed. Based on existing evidence, one could hypothesize that the use of colors in athletic, physical education and recreation facilities could improve or impede motor performance (Rudisill, 1981).

There is a great need for physical educators, coaches and recreators to determine the factors that could have a bearing on the motor performance of individuals. An obligation of the professionals in the field of physical education should be to provide environmental situations that could improve a performer's efficiency. With the emphasis that color has on individuals' lives, the utilization of colored lighting could definitely be a factor to consider for improving motor performance and other selected physiological variables.

Statement of the Problem

The purpose of this study was to determine the effects of lighting conditions (blue, red and white) on the variables of blood pressure, heart rate, and temperature in the performance of two groups of racquetball players.

A secondary purpose was to determine if the performance of Group 1 (highly skilled) and the performance of Group 2 (skilled) differed significantly under the color conditions of blue, red, and white light.

Additionally, the study examined the emotional perceptions of racquetball players relative to their performance under the color conditions of blue, red, and white lights.

Scope of the Study

On March 16, 17, and 18, 1982, at Appalachian State University, Boone, North Carolina, 19 skilled and highly skilled racquetball players completed a racquetball skills test devised by East, Hensley and Stillwell (1979). Four of the subjects were determined to be highly skilled; the remaining 15 were skilled players. The subjects' ages ranged from 20 years 4 months to 52 years 4 months, with a mean age of 27 years and 11 months. The subjects volleyed under the following conditions: (1) with blue lighting; (2) with red lighting; and (3) with white lighting.

Pre-test and post-test readings were recorded on each subjects' blood pressure, heart rate, and temperature, and motor performance was also measured during the racquetball wall volley tests.

Definition of Terms

For the purpose of clarification, the following terms employed in this study have been defined.

Blue Lighting. Blue lighting is a color that represents the ultraviolet end of the spectrum. A blue surface absorbs the long and medium long wavelengths and reflects the short ones to produce the sensation of blue. Blue is a primary color.

Chroma. Chroma is the strength or weakness of a chromatic color. Chroma is the brightness or darkness of a color and is described as weak, moderate, or strong.

General Performance. General performance is a formal demonstration of a skill or talent.

Highly Skilled Racquetball Players. Highly skilled racquetball players are individuals who have placed in the final four of an intramural racquetball open tournament over preceeding years and judged to be highly skilled by a panel of authorities.

Hue. Hue is distinguishing one color from another. It is the classification of colors (red, yellow, green, and blue).

Motor Performance. Motor performance is the ability to carry out particular physical tasks and movement skills.

Physiological Parameters. The physiological parameters include blood pressure, heart rate and temperature.

Red Lighting. Red lighting represents the infrared end of the spectrum. A red surface absorbs the short wavelengths of light. The long wavelengths are reflected and enter the eye where they stimulate the red receptors of the retina. Red is a primary color.

Skilled Racquetball Players. Skilled racquetball players are individuals who have participated in an intramural open tournament and advanced through at least three rounds of the tournament and judged to be skilled by a panel of authorities.

Value. Value is distinguishing a light color from a dark one. Value indicates how light or how dark a given color may be.

White Lighting. (Normal lighting) White lighting reflects light containing all of the visible rays of the spectrum. White is a neutral color of very high value.

Limitations

The results of the study were subject to the following limitations:

1. The courts employed were not of regulation size causing restricted conditions when the long-wall volley test was performed;

2. Outside factors such as cars, horns, voices, etc., were present during the testing that could have distracted the subjects;

3. There were no controls on the emotions of the subjects for each testing trial;

4. The normal lighting in the courts could have been a factor on performance;

5. No warm-up sessions were provided prior to testing and individually this may have affected the subjects;

6. The subjects used personal racquets during testing, rather than a standard testing racquet;

7. The sample size was small;

8. There was no control on the activities in which each subject was involved prior to each testing session.

Chapter 2

REVIEW OF LITERATURE

Many views exist concerning the psychological effect of color on performance; however, there was an absence of related literature dealing with the physiological effects of color on motor performance. For this reason, the author chose to include both relevant related literature as well as peripherally related information. The review of literature is divided into five parts: (1) color effects on physiological variables; (2) color effects on psychological and emotional variables; (3) color and effects on perceptual variables; (4) color effects on preference, and (5) summary.

Color Effects on Physiological Variables

Many studies have revealed that colors do influence a number of physiological factors. Such studies have involved the measure of physiological processes and motor performance of certain individuals while exposed to certain colored lighting conditions.

Deutsch (1937), during his practice, found that color influenced changes in blood pressure and pulse rate. Deutsch exposed many patients to various colored environmental situations and found that when a patient was placed in a red or green lighted environment, the patient's blood pressure and pulse rate either increased or decreased. It was concluded that the psychic make-up of the individual determined the appropriate color employed to achieve desirable results.

Birren (1961) also supported the concept concerning the influence of color on blood pressure and heart rate. However, Birren concluded that red acted to raise blood pressure and pulse rate and that blue decreased blood pressure and heart rate. The effects were not always permanent though, since after a period of time a reversal in the effects occurred.

In addition to Birren's findings involving the influence of color on blood pressure, Birren (1970) also stated that with palmer conduction (electrodes in the palm of the hand which indicate changes through reaction of the sweat glands), the colors red and blue produced immediate increases of heat; although arousal after a period of time was consistently higher for red than for blue.

Gerard (1958) investigated the effect of different colors on psycho-physiological measures indicative of emotional changes. Blue, red, and white lights of equal brightness were each projected for 10 minutes on 24 normal male adults. The automatic nervous system and visual cortex were significantly less aroused during blue than during red or white lighting. Different colors also elicited significantly different feelings such as: greater relaxation; less anxiety and hostility during blue lighting; more tension and excitement during red lighting.

Another physiological factor affected by various colored lighting situations was the rate of breathing. It was found that the rate of breathing increased under red lighting and decreased under blue lighting (Podolsky, 1938). An earlier study completed by Pressy (1921) involving color lighting effects on breathing rate, indicated results contrary to those of Podolsky. Twenty-six male and female subjects performed various mental and motor tasks under the exposure of various colored lighting conditions. While stationed seated at a table with a particular color being shown upon the table top, each subject's rate of breathing was observed for 12 to 15 minutes. The test situation was conducted in such a manner that the subjects' entire bodies were not exposed to the light; instead, the colored light was shining only on the surface of the table. Pressy indicated that the ability for an individual's body to be fully affected by a lighting condition would require total body exposure.

Galvanic skin response was tested under violet and green colored lighting situations (Nourse & Welch, 1971; reported by Plack & Shick, 1974). When alternately exposed to both colored lighting situations, subjects exhibited a greater galvanic skin response to violet lighting than to the green. There was a significant increase in the responses when exposed to either colored lighting condition as opposed to white (normal) light.

There also appeared to be a relationship between color and heart rhythm (Deutsch, 1937). Deutsch treated patients with disturbances in heart rhythm by placing the patient in a room overlooking a garden. The room consisted of windows with glass panes arranged to accommodate different hues. Within the room itself, artifical colored lighting was employed to relax or stimulate the patient. Deutsch concluded that this type of color therapy had a noticeable effect on the patient's heart rhythm.

Podolsky (1938), as reported by Birren (1961), observed a change in muscular activity when comparing the effects of ordinary white lights to colored lights. Podolsky reported that the results found under ordinary lights indicated the muscular activity registered 23 units but increased with colored lights. The subjects registered the following scores under different colored lights exposures: 24 units with blue; 28 units with green; 30 units with yellow; 35 units with orange; and 42 units with red. The units were gathered by totaling scores of various muscular activities.

A study by Bross and Jackson (1981) concluded that room color influenced motor performance. The authors observed the effects of preferred and nonpreferred room color on mirror-tracing performance. Girls from seventh, eighth and ninth grades participated in the practice of mirror-tracing in a neutral colored room before being tested in pre-

preferred and nonpreferred colored rooms. The errors decreased significantly in the preferred room, while the time to complete the task changed minimally. Bross and Jackson concluded that the hypothesis of room color affecting performance was only partially supported. The fact that the junior high girls made fewer errors in the preferred colored room supported the research that preferred or liked colors may have decreased muscular tension within the individual (Birren, 1969; Daniel, 1939; Freeman, 1938). The results indicated that motor performance was influenced by color.

Shick (1975) completed an investigation to determine what effect the color of a target had on throwing accuracy. Shick tested 39 volunteer college women by having them throw a regulation softball at a colored target 25 feet away. The target colors were red, yellow, green, blue, black, and white. The results indicated no significant differences in performance scores as related to color. Shick concluded that from a distance of 25 feet, a target of a single color does not seem to affect the throwing accuracy of college women. However, other studies have contradicted Shick's findings, indicating that color has an effect on the visual perception of an object (Bevan & Duke, 1953; Birren, 1961; Sato, 1955). Such studies have indicated that there is a perceived effect of color on size, rather than on throwing accuracy.

Through a combination of studies, similar effects were found when testing psychomotor responses. Birren (1961) reported a study in which the following conclusions were drawn from testing approximately 300 college students: red lighting increased muscular reactions by 12% in comparison to muscular reactions under normal white lighting conditions and green lighting had a retarding effect on muscular reactions. However, Goldstein (1939) denoted that if efficient movement was desired, that green lighting was preferred over red since movements performed with the same intention were executed more accurately under the green light condition. Goldstein also concluded that mental judgements of common tasks were influenced by green lighting, such as an underestimation of time, length and weight. Podolsky (1938) found that muscular strength, measured with a dynamometer, increased under red lighting.

Color Effects on Psychological and Emotional Variables

Although there has been very little evidence that the colors which surround a person actually affected that person's psychological or emotional state, the following individuals demonstrated that subjects do associate certain colors with specific moods or emotional characteristics (Birren, 1961, 1966, 1970; Gatto, 1974; Kouwer, 1949; Lewinski, 1938; Luckiesh, 1921; Murray & Deabler, 1957; Podolsky, 1938; Sargent, 1923; Schactitel, 1943; Schaie, 1966; Schaie & Heiss, 1964; Spiegal & Keith-Spiegal, 1971).

The red and yellow areas of the color spectrum are most often described as being exciting, stimulating, happy and suggest very active emotional states. In addition, red has been associated with restlessness, agitation, aggressiveness and stimulation. The colors in the red, yellow and orange end of the spectrum were found to increase in "warmth" with the hottest color being red (Schaie & Heiss, 1964). Birren (1970) found that blue was considered as being tranquil and red as being impulsive and aggressive.

The opposite side of the emotional spectrum seems to be symbolized by colors in the blue-green regions. These colors are described as "cool" and have a leisurely, controlled emotionality, and depict tenderness, comfort, security, peace and calm. Characteristic associations depict blue and green as the most pleasant colors for adults (Birren, 1955, 1961, 1970; Podolsky, 1938; Schaie & Heiss, 1964).

Lewinski (1938) conducted an investigation employing colored lights to illuminate the rooms of 25 men and 25 women college students and then asked the subjects to describe the feelings experienced in conjunction with different colored illumination. The results indicated blue and green lights were described as most pleasant and cool; yellow as most unpleasant; both yellow and red as stimulating; purple as depressing; and red as hot (Schaie & Heiss, 1964).

Studies have indicated that colors have psychological and emotional effects upon employees in industry (Papadatos, 1964). Coordinated color selections have increased production 5 to 10%, reduced absenteeism, and helped the morale of the employees. Papadatos also concluded that when surroundings are interesting, students will be more interested in their studies. Bright colors increase bright outlooks of students--stimulating productivity, reducing absenteeism, and promoting positive feelings about school. Birren (1955) also supported this by offering the thorough investigation of the value of color effects on employees in industry, published by the National Industrial Conference Board (1947). Over 350 companies which had used color on either a small or large scale were asked to comment on a series of questionnaires. The results were: 64.7% of the companies stated that color had improved employee morale; 27.9% reported color increased production; 30.9% noted color created an improvement in the quality of work performed; 19.1% commented favorably on reduced eyestrain and fatigue when color was used; and 14.7% credited color for reduced absenteeism.

Heline (1964) found that psychological effects of color had a startling impact on the employees of a London factory. Heline discovered that absenteeism among the women of the factory decreased noticeably once the gray walls were painted beige. By painting the walls beige, the blue lighting that was being used within the factory was reflected less off the wall than when the walls were gray. A color specialist working with the study, indicated that the combination of the gray walls and the blue lighting made the employees look sickly and psychologically feel sickly. In conclusion, the beige paint alleviated the sickly appearances and feelings and decreased the absenteeism greatly.

Certain coaches have successfully employed colors to create desirable emotional reactions from players. Alonzo Stagg, while head coach at Chicago, had two dressing rooms for his players. One was painted blue for rest periods, the other was painted red for fight talks. The athletic director at the University of New Mexico decorated his own football team dressing room with red and that of the visiting opponent team in blue. The purpose of the red dressing room was to stimulate and excite the players. The blue dressing room was created for the exact opposite, to relax the players (Clark, 1975).

Color Effects on Perceptual Variables

Color appears to have had a significant role in human's perception of the physical world. The evidence strongly suggests that one's perception of form, size, weight and distance are all influenced by color (Birren, 1961).

Birren (1961) reported that color suggested the geometric form of objects. For example, orange lent itself to detail and seemed to create the image of a rectangle; while yellow was less substantive, it seemed to lack weight and suggested a pyramid or inverted triangular shape. Blue was frequently blurred from a distance and was related to a circle. Red was a strong color and was amenable to sharp angles and suggested both a square and a cube.

Children are more sensitive to color than to form, as Birren (1961) reported in a study conducted by Katz (1922), in which children, ages three to five were given red triangles and green disks and were asked to select the objects that appeared the same as a red disk. In this context, Birren found that the children interpreted sameness as a matter of color, chosing the red triangles rather than form. This behavior, however, did not persist and the described experimental conditions became ambiguous when older children and adults were tested.

While color did not supercede the adult's perception of form, it did appear to influence perception of size. Bevan and Dukes (1953) reported that there was an overestimation of size for red and yellow but not for blue and green. Sixteen college students, in a relatively natural environment, selected from a series of 14 neutral gray reference cards equal in area to 16 test cards of various sizes and colors. The results indicated judged area to actual area revealed reliable errors of overestimation, comparable in magnitude, for the red and yellow cards, no error for blue or green. Errors of estimation were found to vary with size of stimulus-card, indicating that the size of the cards was not the factor involved in the judgement of the colored cards. Plack and Shick (1974) summarized an investigation by Sato (1955) indicating that the estimated size of identical surfaces varied with color; orange and yellow were overestimated, blue was underestimated, green and purple were neither overestimated nor underestimated, red was uncertain, and white appeared larger than black.

Apparent weight is another perceptual variable greatly affected by color. Payne (1964) conducted a series of studies to determine the effects of color on apparent weight by using an observation procedure. Order of apparent weight was (heavier to lighter) blue, red, yellow, reddish-purple, turquoise, and green. Several studies reported that darker colors such as black, red, and blue were judged as heavier than the lighter colors of green, yellow, and white (Birren, 1961; Payne, 1964; Pressy, 1921). Payne also concluded that although color did influence the perception of apparent weight, the extent of the influence was not as great as that of the lighting intensity on weight. Pressy (1921) also supported Payne's findings in that bright colors were perceived to weigh more than dark ones.

Color has also been found to affect perceived distance. Taylor and Summer (1945) completed an investigation to determine what effect various colors had on apparent distance. A total of 11 subjects were seated at the end of a long, black table, while colors were presented in various depth perceptions by an apparatus that was situated on poles in front of the subject. Taylor and Summer concluded that at a constant distance light colors appear nearer than dark colors. Birren (1961) reported that the color blue appeared further away. Birren explained this phenomenon by pointing out that red, focused behind the retina and caused the lens to become convex, thus pulling the color nearer. Conversely, blue created the opposite response by focusing in front of the retina, causing the lens to flatten out and push the color back.

Podolsky (1938) found that the more abstract percept of warmth was greatly affected by color. In the presence of colors such as red, orange, and yellow, subjects reported a psychological feeling of warmth. It was found in one study, that when an office was painted blue after being yellow, the stenographers began to complain about the cold even though the thermostat had not been changed. Raising the actual temperature of the office did not decrease the complaints. When the office was repainted yellow, the complaints ceased even when the thermostat was turned down. Newhall (1956) had 201 subjects select the warmest and coolest colors from a color chart and concluded that red and yellow-reds were the thermally warmest hues and that the cold hues ranged from yellow, through green and blue, to purple. There was an overlapping of the warm and cool colors in the yellow and the purple-blue regions. This overlapping could have been due in part to conflicting associations that the subjects had for these particular colors.

Clark (1978) supported Newhall's (1956) findings with an investigation completed in a factory cafeteria. The cafeteria was air conditioned and had light blue walls and the employees complained of the cold, though the temperature was 72 degrees. After the temperature was raised to 75 degrees, there was still no change in the employees' complaints. Finally, a color consultant advised repainting the walls orange. The employees then complained that the 75 degree temperature was too warm. The temperature was finally reduced to 72 degrees and the employees were then content.

Color Effects on Preference

Research has indicated that color preferences and their patterns of development seemed to be relatively cross-cultural (Child & Iwao, 1969; Garth, 1922; Garth, Ikeda & Langdon, 1931). Although some differences have been found, none have been considered significant enough to invalidate the findings that color preferences were cross-cultural (Choungourian, 1969). All young children tested seemed to prefer warm, bright colors with a shift in emphasis with increasing age to cool, less saturated colors (Birren, 1950; Ellis, 1900, 1906; Staples, 1932; Child, Hansen & Horbeck, 1968).

All types of age groups and individuals respond to colors differently. Birren (1961) reported that three month old babies attend to yellow, white, pink and red with very little attention to black, green, blue, and violet. Staples (1932) reported the preference order of two year olds and young children was red, green, blue, and yellow and that a noticeable decline in the preference for yellow was also recorded by Birren (1961), as well as the following color preference order: red, blue, green, violet, orange, and yellow.

The positions of the last three colors of preference, as recorded by Birren (1961), (violet, orange, yellow), remained relatively constant with maturity, while blue ranked first in preferences, above all other colors, in nearly all investigations (Birren, 1961; Guilford, 1959; Guilford & Smith, 1959; Simon, 1971; Staples, 1932).

Three studies that have been conducted have concluded that chroma and value may affect color preference, in addition to hue (Child & Iwao, 1969; Guilford, 1959; Plack & Shick, 1974). In general, the more saturated (higher chroma) colors were preferred over less saturated (lower chroma) colors such as: light blue preferred over dark blue. The conflicts which do arise between hue and chroma preference resulted in significant predominance of hue over chroma. This preference increased with age and no generalizations were made from the findings related to value.

There also appears to be a relationship between color preference and personality characteristics (Birren, 1961; Podolsky, 1938; Spiegal &

Keith-Spiegel, 1971). Extroverts prefer warm colors, mainly red as being the most favorite. Introverts preferred cool colors, mainly blue as the most favorable. Neurotics selected significantly more red and purple than extroverts did. Egotists appeared to prefer yellow over all the other colors. Anxiety was also found to be associated with yellow among females along with a dislike for green and males had a dislike for blue.

Shick (1977) conducted a study seeking to find a relationship between personality and color in the performance of a gross motor skill. Thirty-nine volunteer college women were administered the Thurston Temperature Schedule, that measured specific characteristics, in addition to completing a target accuracy test that consisted of a total of 50 throws at 10 colored targets. Shick concluded from the results that no relationship existed between personality and color as it affected performance of a gross motor skill.

Summary

The research that was reviewed for the purpose of this investigation supports the hypothesis that color has an effect on the physical, psychological and emotional abilities of an individual and the proper utilization of various colors can enhance physical and motor performance. Studies have revealed that color and colored lighting affected blood pressure, heart rate, heart rhythm, and galvanic skin response. Psychologically color affected individual feelings and emotions as well as the overall response to a particular activity or situation. Further, perceptual variables and color preference also had an impact on the effects of color on individuals.

Chapter 3

PROCEDURES

Chapter 3 outlines the procedures employed in testing a group of four highly skilled and a group of 15 skilled racquetball players under blue, red, and white lighting. The subjects' blood pressure, heart rate, and skin temperature were recorded both before and after a racquetball wall volley test, performed under each lighting condition.

The procedures are divided into five sections within this chapter including: pilot study, selection of subjects, testing treatment, testing procedure, and statistical treatment.

Pilot Study

On November 12, 1981, three highly skilled and six skilled racquetball players performed a validated wall volley test. Each player was randomly selected to be tested under the blue, red, and white lighting conditions on all three nights of testing. The test involved volleying a ball for 30 seconds, once from the short line and once for 30 seconds from 12 feet behind the short line. A count was taken of the number of legal hits of the ball against the front wall for the short and long volley tests. A total performance score for each color condition was calculated. Blood pressure, heart rate, and temperature were taken 10 seconds before each wall volley test and within 10 seconds after each test was completed.

The data were analyzed utilizing an analysis of variance. An $F = 8.75$ ($\underline{p} < .05$) was found between body temperature and colored lighting conditions. There was no significant difference found for blood pressure, heart rate, and performance under the colored lighting conditions. A Tukey test analysis for the temperature and the three colored lighting conditions indicated that the significant difference was within the white lighting condition. This difference indicated that the temperatures decreased under the white condition.

Selection of Subjects

The subjects tested were selected from the leading racquetball players at Appalachian State University, Boone, North Carolina. A total of 19 subjects, one female and 18 males, were selected from the 1981 racquetball intramural competitions.

The subjects were assigned to one of two groups. Group 1 consisted of four highly skilled racquetball players and Group 2 consisted of 15 skilled players. The ranking for each group was established from the results of each subject's final placement in the Appalachian State University intramural competitions and by a panel of racquetball authorities. The authorities consisted of two physical educators and a sociology instructor who were regional racquetball tournament finalists. The authorities' ratings were done separately and without knowledge of intramural standings. Subjects were assigned to the highly skilled group according to the rankings of the racquetball authorities and if they had been in the final four of an intramural racquetball open tournament over the preceeding years. Subjects were assigned to the skilled group by the rankings of the authorities and had to have participated in an intramural open tournament and advanced through at least three rounds of the tournament.
The subjects' ages ranged from 20 years 4 months to 52 years and 4 months. The mean age of the subjects was 27 years and 11 months. The subjects' racquetball playing experience ranged from 12 years and 0 months to 0 years and 11 months. The mean playing experience was 5 years and 8 months.

Testing Treatment

The testing device employed in this study was a racquetball skills test devised by East, Hensley and Stillwell (1979). This test was successfully used by Weston to test auditory cues on performance (1980). The test comprised both a short-wall volley test and a long-wall volley test.

The test required each of the subjects to volley the ball against the front wall of the test court for two, 30-second periods; one point being scored each time the ball hit the wall legally. The two, 30-second periods consisted of one short-wall volley test and one long-wall volley test. Both the short-wall and long-wall tests were utilized and the total score was the sum of the legal hits of the two trials. No points were scored when a subject stepped over the restraining line to volley the ball or when the ball hit the floor on the way to the front wall.

East, Hensley and Stillwell (1979) determined the reliability of the long-wall volley test to be $\underline{r}$ = .82 for women and $\underline{r}$ = .85 for men. For the short-wall volley test, the reliability was determined as $\underline{r}$ = .86 for women and $\underline{r}$ = .76 for men. There were no substantial differences between men and women in the validity of the two tests. Therefore, the validity coefficients for men and women combined were $\underline{r}$ = .79 for the short-wall volley and $\underline{r}$ = .86 for the long-wall volley test.

Further, the correlation between the short-wall volley and long-wall volley test was determined to account for approximately 54% of this error. This suggested that the racquetball skills test was statistically acceptable for use in this investigation.

Testing Procedure

Each subject was scheduled to participate all three nights at the same time, between the hours of 9 and 11 p.m. in order to decrease external variables, such as outside noise and court noise. After proper explanation and demonstration (Appendix A), the subjects had the opportunity to practice the test for two minutes prior to the initial testing in order to better understand and to learn the testing procedures. After the practice, the subjects sat in a normal court for 10 minutes to achieve a resting state before proceeding with the testing. The court temperature ranged between 22.2 C to 23.0 C the first night of testing, 20.5 C to 22.1 C the second night, and 22.7 C to 23.6 C the third night.

The test consisted of the subjects sitting in the testing court for two minutes, then performing two, 30-second trials; one from behind the short line and the other one from the long line marked on the floor 12 feet behind the short line. Each subject began the test by holding two balls. Two additional balls were held by the timekeeper who was located within the court near the back wall.

The subjects stood behind the short line, dropped a ball, and volleyed it against the wall for 30 seconds. Each subject was required to hit the ball from behind the short line. The ball could be hit in the air after rebounding from the wall or could be hit after bouncing. There were no restrictions on the number of bounces the ball could take before being hit. If the ball did not return past the short line, the subject was allowed to step into the front court to retrieve the ball, but had to return past the short line for the succeeding stroke. If the subject missed the ball, a second ball could be put into play in the same manner as the first, or the subject could retrieve the missed ball and continue to volley.

If both of the initial balls were missed, the subject had the option of obtaining a new ball from the timekeeper or retrieving a missed ball and putting it into play in the same manner as the first. Any stroke could be utilized in order to keep the ball in play. At the end of each testing session, the subjects completed a mini-questionnaire concerned with feelings and reactions to the colored lighting condition that had just been completed (Appendix B). In addition, a comprehensive questionnaire at the completion of all the tests was also filled out by the subjects (Appendix C). Both the mini-questionnaire and the questionnaire were devised by the author.

Motivation is a key aspect to consider in performance. For this reason, each subject was informed before the testing that the individuals with the highest total performance points from the highly skilled group and from the skilled group would win $25 each.

Prior to each testing session, all subjects were asked to complete an Emotional Outlook and Playing Checksheet. The checklist included questions dealing with the subjects' emotional status, such as major negative happenings and personal problems (Appendix D).

The testing area in which the study was administered was racquetball court numbers 19, 20, and 21 in Varsity Gymnasium, Appalachian State University, Boone, North Carolina. The area of each court measured 32.5 feet by 20 feet by 20 feet. The lighting employed was from the overhead lights with 150 watt white bulbs utilized on the red and white courts and 300 watt white bulbs utilized on the blue court. A foot candle meter was utilized to measure the intensity of light, which registered 12 foot candles at the front of the courts, 8 foot candles of light at the service line, and 6 foot candles against the back wall of the court. All courts registered the same intensity of light even though bulb wattage was different. This was caused by light filtration of the various color conditions within the courts.

The color of the red and blue cellophane which was used to cover all lights in the colored courts was measured in conjunction with the Appalachian State University Physics Department. A spectrophotometer was utilized to measure the transmission curves for the red and blue cellophane.

The transmission of light was measured by wavelengths that varied from 400 nanometers (NM), representing the blue (short wavelengths) end of the spectrum, to 700 nanometers, representing the red (long wavelengths) end of the spectrum. The results of the spectrophometer are included in Figure 1 and Figure 2. Figure 1 represents the red cellophane transmission of light. A small percentage of blue was transmitted through the red cellophane, in addition to a high percentage of red.

Figure 1

Red Cellophane Transmission

Curve Graph

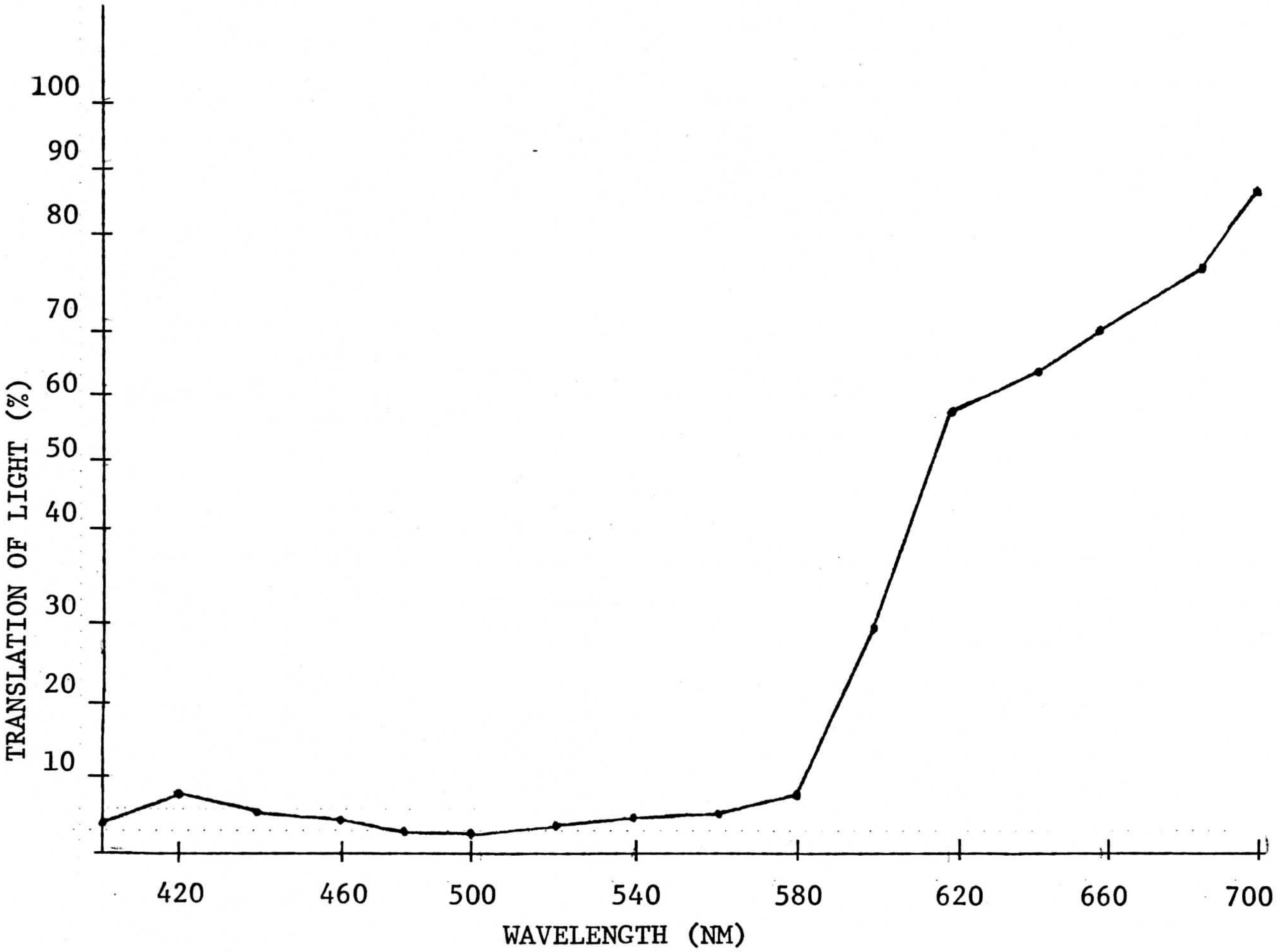


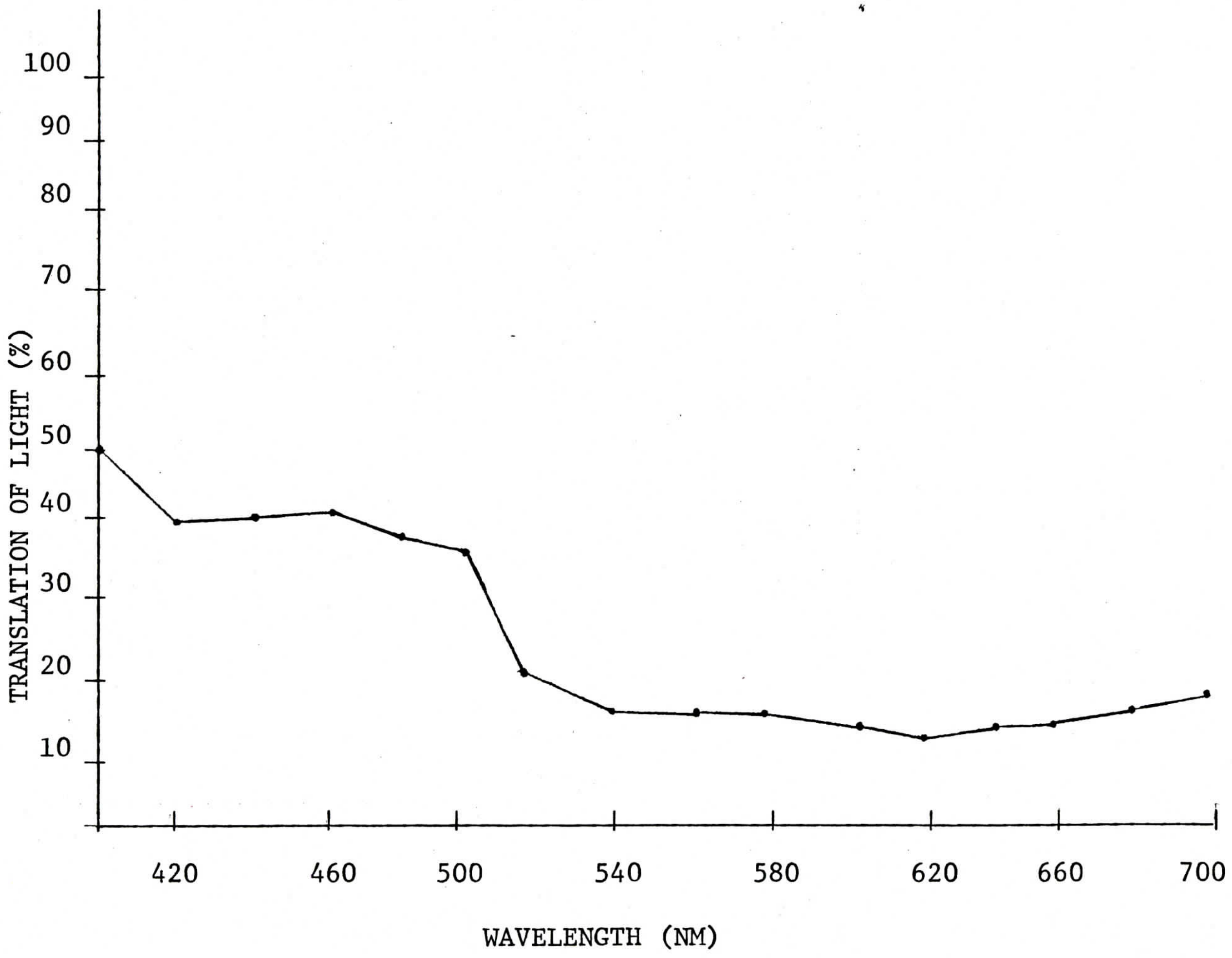
Figure 1 represents the transmission of light through red cellophane in percentages. (Readings were measured by Dr. Karl Mamola, Department of Physics and Astronomy, Appalachian State University.)

Figure 2 represents the blue cellophane transmission of light. A large percentage of blue and green were present in addition to a small percentage of yellow, orange, and red.

Figure 2

Blue Cellophane Transmission

Curve Graph



This graph represents the transmission of light through blue cellophane in percentages. (Readings were measured by Dr. Karl Mamola, Department of Physics and Astronomy, Appalachian State University.)

Equipment pertinent to the testing portion of the study included a Tycos Pre-Calibrated Blood Pressure Cuff; a Littman Stethoscope manufactured by Diagnostic Products; Markson Thermometer, Model Number 94, manufactured by Markson Science, Inc.; and five rolls of both red and blue cellophane, each roll consisted of 150 inches by 20 inches of cellophane. Other equipment included the subjects' own racquetball racquets, 12 new regulation Voit Rollout Blue Racquetballs, floor marking tape, yard stick, wall tape, and one Cronus Single Event Stop Watch, manufactured by Cronus Precision Products, Inc.

The personnel employed in the testing consisted of a timekeeper, a scorer, a recorder operator, and three attendants to take blood pressure, heart rate, and temperature. The attendants used were Graduate Assistants who had completed a Lab Techniques course in addition to having experience time working in the Human Performance Lab at Appalachian State University. Inter-rater Reliability was assumed with the use of the three attendants. The scorer was positioned on the balcony overlooking the test court and counted all legal hits of the ball against the front wall within the one minute period. The timekeeper remained in the court with the subjects being tested and timed the test and retrieved balls for the subject. The recorder was located outside the court and recorded the blood pressure, heart rate, temperature readings, and performance scores of each subject. The three attendants took the readings and relayed them to the recorder, both 15 seconds prior to the wall volley test and within 15 seconds after the completion of the tests. Skin temperature was taken on the distal end of the left index finger and pulse rate was taken at the right carotid artery. Both heart rate readings were taken for a period of 10 seconds. The physiological readings prior to the testings were taken inside a normal white court; and when the testing was completed, the subject was seated inside the testing court where the remainder of the readings were recorded.

Each subject was tested under the following conditions: (1) blue lighting, (2) red lighting, and (3) white (normal) lighting. The subjects spent a total of three minutes exposure to each color condition with two minutes of sitting exposure and one minute of volleying exposure. The conditions for testing each subject were selected by random choice. The subjects were randomly assigned to each condition on the three testing nights (red, blue, and white).

Statistical Treatment

An analysis of variance with repeated measures having one grouping factor and two trial factors was utilized for the computations of blood pressure, heart rate, and temperature. The two trial factors being the type of lighting conditions (blue, red, and white) and the pre-test and post-test measures of blood pressure, heart rate, and temperature for both groups of highly skilled and skilled players.

Biomedical Data Processing 2V (BMDP 2V), Analysis of Variance and/or CoVariance Including Repeated Measures was used to treat one grouping factor and two trial factor data (Biomedical Computer Programs, 1979). The BMDP 2V utilizes the test for compound symmetry to determine homeogeneity of variance and covariance.

An analysis of variance with repeated measures having one grouping factor and one trial factor was used in order to determine if the highly skilled players' performance was significantly different from the skilled players. BMDP 2V Analysis of Variance Including Repeated Measures was used to treat one grouping factor and one trial factor.

On the variable of temperature, a Bartlett test was used for homeogeneity of variance because compound symmetry was not met. Homeogeneity of variance was met for blood pressure, heart rate, and performance.

The .05 level of confidence was employed to determine significance for all statistical analysis. All statistical analysis was conducted on a Univac 90/80 computer at Appalachian State University, Boone, North Carolina.

The mini-questionnaire and questionnaire were measured according to the percentage of responses to each question. The mini-questionnaire and questionnaire were both devised by the author.

Chapter 4

RESULTS AND DISCUSSION

Included in this chapter is a presentation and discussion of the results of the investigation.

Results

The BMDP 2V statistical package yields specific descriptive information relative to variables measured within this study. As a result of the data collected within this investigation, the following descriptive information is presented.

Tables 1, 2, 3, and 4 represent the descriptive information concerning the means and standard deviations for the effects of color conditions (blue, red, and white) on the independent variables of diastolic blood pressure, systolic blood pressure, heart rate, and temperature for Group 1 (highly skilled players) and for Group 2 (skilled players) respectively. Pre-test and post-test readings are presented for each independent variable.

No significances were found among blue, red, and white lighting conditions and diastolic blood pressure, systolic blood pressure, heart rate, and temperature of Group 1 (highly skilled) and Group 2 (skilled) racquetball players. Tables 5-8 represent the statistical information concerning the analysis of variance with repeated measures on the effects of the color conditions (blue, red, and white) on each of the main effects. There was no significance reported. The test for homeogeneity of variance and covariance for each main effect (except temperature) was determined to be significant at the .05 level. Bartlett's test for homeogeneity of variance was conducted on temperature and was determined to be significant, $F(1,17) = .72$, at the .05 level of confidence.

Table 1

Effects of Color Conditions on Pre- and Post-

Test Diastolic Blood Pressure

	Color Conditions		
Groups	Blue	Red	White
Group 1			
M Pre-Test	137.25	135.50	140.00
M Post-Test	189.00	181.50	171.00
SD Pre-Test	29.81	12.68	21.72
SD Post-Test	29.05	25.10	39.51
Group 2			
M Pre-Test	117.73	114.00	114.66
M Post-Test	164.00	159.66	162.00
SD Pre-Test	12.84	11.33	13.70
SD Post-Test	20.41	33.44	25.43

Table 2

Effects of Color Conditions on Pre- and Post-

Test Systolic Blood Pressure

Groups	Color Conditions Blue	Red	White
Group 1			
M Pre-Test	87.50	82.00	76.00
M Post-Test	71.00	80.50	75.50
SD Pre-Test	4.43	5.65	9.93
SD Post-Test	21.69	11.81	13.10
Group 2			
M Pre-Test	70.06	72.00	74.80
M Post-Test	62.53	58.53	60.40
SD Pre-Test	7.44	8.91	10.46
SD Post-Test	23.58	18.98	16.03

Table 3

Effects of Color Conditions on Pre- and Post-

Test Heart Rate

	Color Conditions		
Groups	Blue	Red	White
Group 1			
M Pre-Test	12.75	14.25	13.00
M Post-Test	25.00	26.50	25.50
SD Pre-Test	2.75	2.36	1.41
SD Post-Test	2.82	3.10	3.51
Group 2			
M Pre-Test	13.20	12.66	13.26
M Post-Test	25.46	25.80	25.33
SD Pre-Test	2.54	1.63	2.71
SD Post-Test	3.71	3.38	4.20

Table 4

Effects of Color Conditions on Pre- and Post-

Test Temperature

Groups	Color Conditions: Blue	Red	White
Group 1			
M Pre-Test	29.75	28.65	28.80
M Post-Test	28.07	26.90	27.32
SD Pre-Test	2.78	3.33	3.33
SD Post-Test	1.96	3.42	3.42
Group 2			
M Pre-Test	29.67	29.21	29.70
M Post-Test	26.98	27.10	27.62
SD Pre-Test	3.05	3.24	3.16
SD Post-Test	2.02	2.49	2.10

Table 5

Source of Variance Table of Color Effects

on Diastolic Blood Pressure

Source of Variance	ss	df	ms	F
Within Subjects				
Group Levels	7857.24	1	7857.24	4.44
Error	30068.94	17	1768.76	
Main Effects				
Colors	379.80	2	189.90	0.79
Error	8191.22	34	240.91	
Diastolic	37806.80	1	37806.80	104.47*
Error	6151.94	17		
Interactions				
Color x Diastolic	318.70	2	159.35	0.83
Error	6548.22	34	192.59	
Color x Group	97.94	2	48.97	0.20
Error	8191.22	34	240.91	
Diastolic x Group	58.21	1	58.21	0.16
Error	6151.94	17	361.87	
Color x Diastolic x Group	410.66	2	205.33	0.83
Error	6548.22	34	192.59	

*$p < .05$

Table 6

Source of Variance Table of Color Effects

on Systolic Blood Pressure

Source of Variance	ss	df	ms	F
Within Subjects				
Group Levels	2895.10	1	2895.10	4.66
Error	10556.05	17	620.94	
Main Effects				
Colors	33.26	2	16.63	0.14
Error	3988.31	34	117.30	
Systolic	1529.05	1	1529.05	6.28*
Error	4138.10	17	243.41	
Interactions				
Color x Systolic	87.17	2	43.58	0.37
Error	3968.93	34	116.73	
Color x Group	197.05	2	98.52	0.84
Error	3988.31	34	117.30	
Systolic x Group	150.32	1	150.32	0.62
Error	4138.10	17	243.41	
Color x Systolic x Group	507.80	2	253.90	2.18
Error	3968.93	34	116.73	

*$p < .05$

Table 7

Source of Variance Table of Color Effects

on Heart Rate

Source of Variance	ss	df	ms	F
Within Subjects				
Group Levels	0.84	1	0.84	0.03
Error	536.48	17	31.55	
Main Effects				
Colors	6.73	2	3.36	0.52
Error	221.09	34	6.50	
Heart Rate	2918.57	1	2918.57	315.44*
Error	157.28	17	9.25	
Interactions				
Color x Heart Rate	0.74	2	0.37	0.24
Error	52.76	34	1.55	
Color x Group	8.73	2	4.36	0.67
Error	221.09	34	6.50	
Heart Rate x Group	0.11	1	0.11	0.01
Error	157.28	17	9.25	
Color x Heart Rate x Group	1.41	2	0.70	0.46
Error	52.76	34	1.55	

*$p < .05$

Table 8

Source of Variance Table of Color Effects

on Temperature

Source of Variance	ss	df	ms	F
Within Subjects				
Group Levels	0.33	1	0.33	.01
Error	516.97	17	30.41	
Main Effects				
Colors	5.47	2	2.73	0.62
Error	150.40	34	4.42	
Temperature	72.95	1	72.95	30.81*
Error	40.25	17	2.36	
Interactions				
Color x Temperature	0.52	2	0.26	0.16
Error	56.56	34	1.66	
Color x Group	4.99	2	2.49	0.56
Error	150.40	34	4.42	
Temperature x Group	2.04	1	2.04	0.87
Error	40.25	17	2.36	
Color x Temperature x Group	0.34	2	0.17	0.10
Error	56.56	34	1.66	

*$p < .05$

Table 9 represents the descriptive information concerning the means and standard deviations for the effects of the color conditions (blue, red, and white) on the independent variable of performance.

Table 9

Effects of Color Conditions on Performance

	Color Conditions		
Groups	Blue	Red	White
Group 1			
M	44.50	43.75	43.00
SD	2.64	3.77	1.15
Group 2			
M	35.60	36.06	35.26
SD	6.10	6.12	7.20

Analysis of data indicated that there was no significance between the effects of the color conditions (blue, red, and white) on the performance of Group 1 (highly skilled) and Group 2 (skilled) racquetball players. Table 10 represents the statistical information concerning the analysis of variance with repeated measures on the effects of the color conditions (blue, red, and white) on performance.

In an attempt to determine whether any group differences between the highly skilled and skilled racquetball players occurred, an analysis of variance with repeated measures on the same subject was computed. A significant difference of $F\ (1,17) = 8.29$, $p < .05$ was found. The analysis of the group difference is also summarized in Table 10.

Table 10

Source of Variance Table of Color Effects on Performance

Source of Variance	ss	df	ms	F
Within Subjects				
Group Levels	622.42	1	622.42	8.29*
Error	1275.89	17	75.05	
Main Effects				
Performance	6.15	2	3.07	0.18
Error	575.32	34	16.92	
Interactions				
Performance x Group	2.99	2	1.49	0.09
Error	575.32	34	16.92	

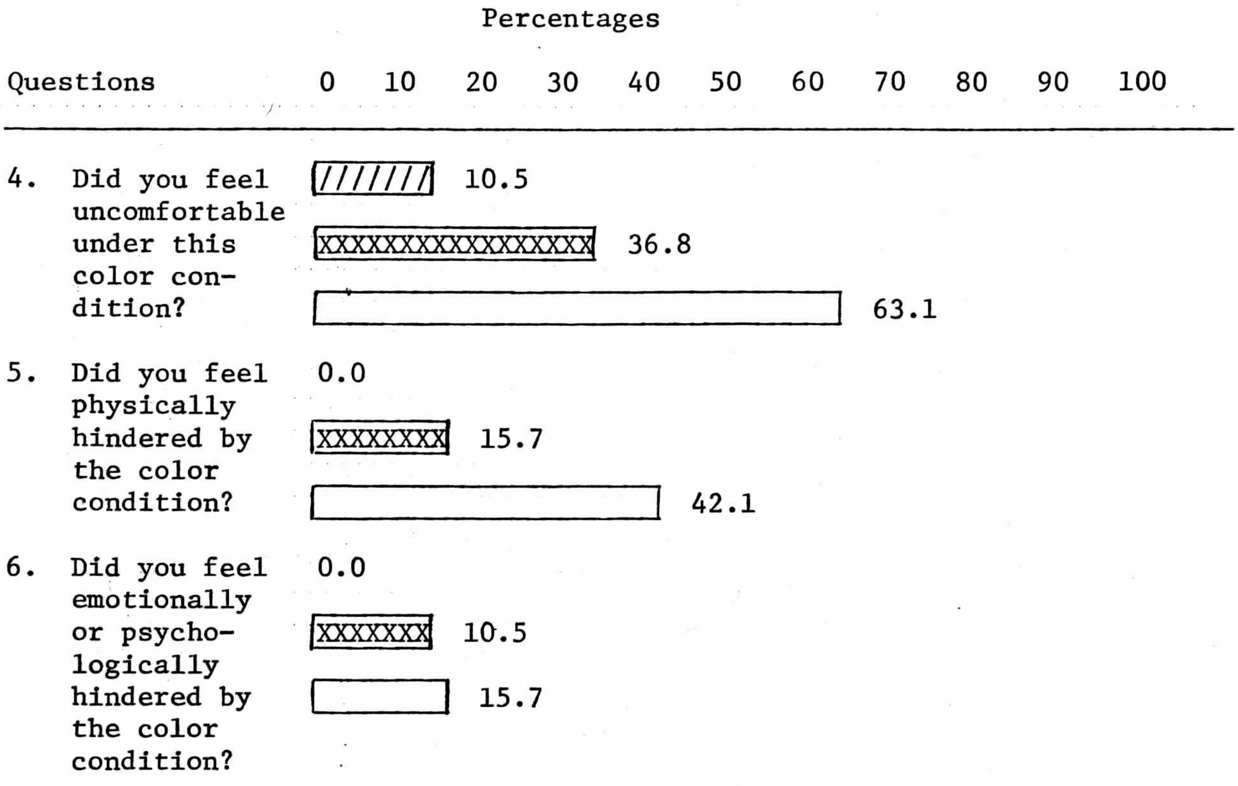
*$p < .05$

The responses to the mini-questionnaire, which was completed by each subject immediately after each testing session, indicated that 63.1% of the 19 subjects felt uncomfortable under the red lighting condition and 36.8% felt uncomfortable under the blue lighting condition. A total of 42.1% of the subjects responded as being physically hindered while being tested under the red lighting condition and 15.7% felt hindered emotionally and psychologically under the red condition. The blue and white conditions had lower percentages dealing with physical and emotional impact compared to the percentages for the red condition. The percentages of responses to the mini-questionnaire are summarized in Figure 3.

Figure 3

Percentage of Responses to Questions

4-6 of Mini-Questionnaire



-Percentages of subjects responding yes to the question.

Key

White ///////

Blue XXXXXXX

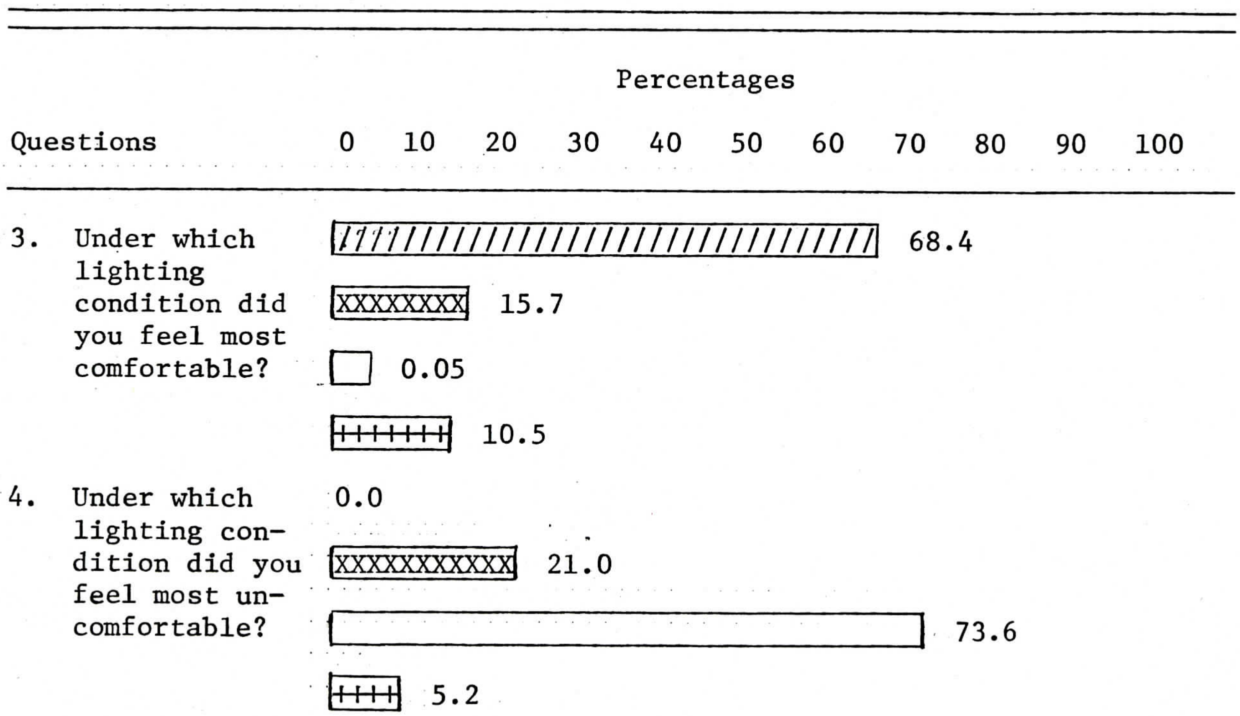
Red [empty box]

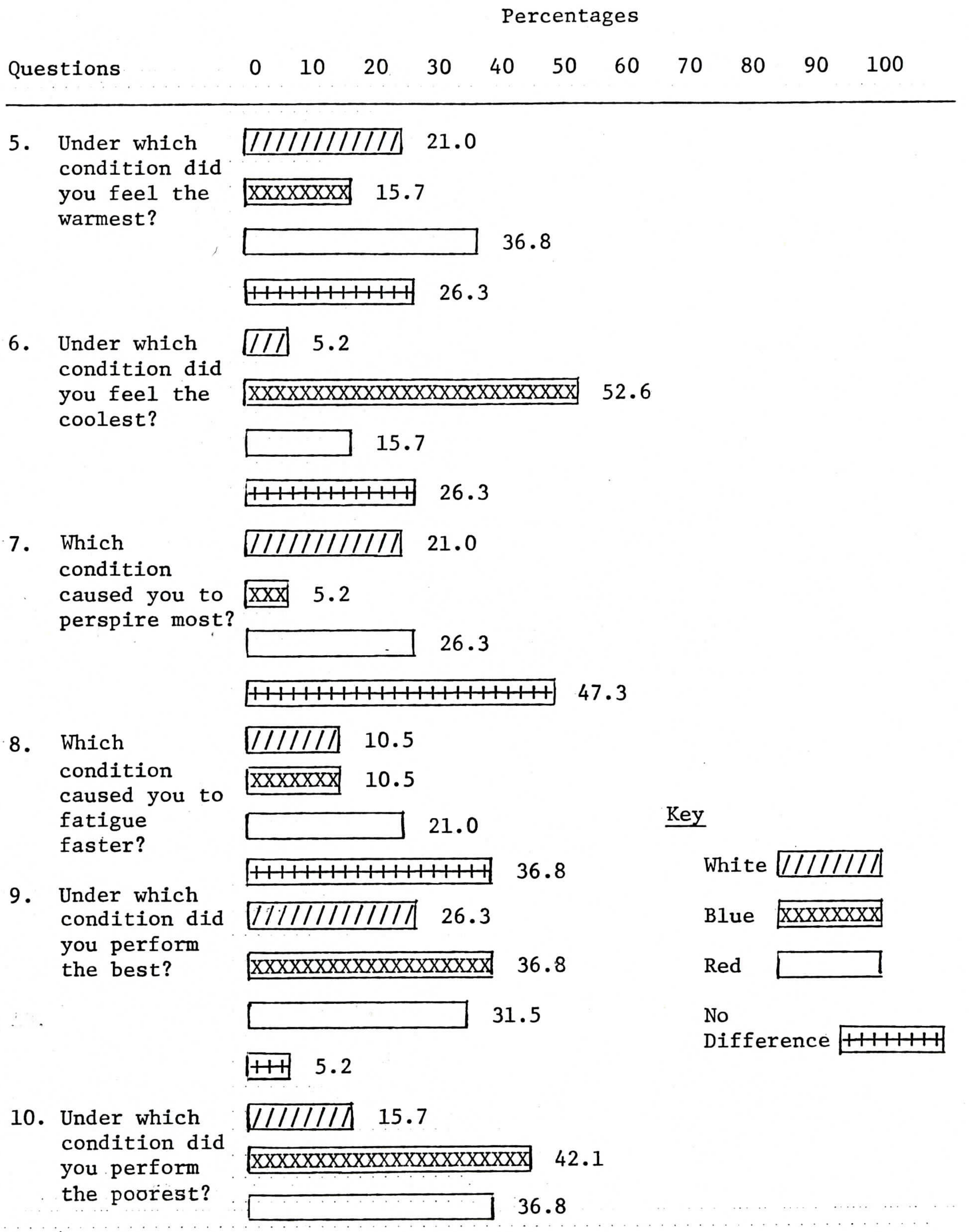
The results of the questionnaire completed by the 19 subjects at the conclusion of the three testing sessions indicated that 68.4% of the subjects felt most comfortable being tested under the white lighting condition; while 73.6% were most uncomfortable while being tested under the red lighting condition. Thirty-six and eight-tenths percent of the subjects responded that the red lighting condition created the warmest sensation; while 21.0% felt warmer during the white condition, and 15.7% indicated that blue was the warmest condition experienced during the testing sessions. Fifty-two and six-tenths percent felt coolest under the blue lighting condition and 15.7% and 5.2% respectively responded that the red and white lighting conditions were the coolest conditions. A total of 42.1% of the subjects indicated that they felt their poorest performance was achieved under the blue lighting condition and 36.8% of the subjects felt that they performed the poorest when under the red lighting condition. (The percentages of responses to the questionnaire are summarized in Figure 4.)

Figure 4

Percentage of Responses to Questions 3-10

of Questionnaire





-Percentages of subjects responding yes to the questions.

Discussion

The results of the investigation indicated that no significant difference occurred in the diastolic-systolic blood pressure, heart rate, temperature, and performance of the subjects under the various colored lighting conditions. The use of color therapy on subjects by Deutsch (1938) and conclusions reached by Birren (1961) concerning blood pressure and heart rate were not supported by this investigation. This discrepency may have been due to the limited three-minute time period the subjects spent in each color condition. This may not have been adequate time for the color conditions to significantly affect the 19 subjects' blood pressure, temperature, and heart rate. The conclusion of Bross and Jackson (1981) that motor performance was influenced by color, was contradictive of the effects the color conditions had on the subjects' performance in this study. Bross and Jackson employed a mirror-tracing activity that did not require the high level of motor performance, including agility, balance, coordination, and cardiovascular endurance that the racquetball wall volley test involved. Since the results of Birren, Deutsch, and Bross and Jackson are contradictive to the findings of this study, it is possible that the low number of subjects employed in this investigation could have caused this discrepancy.

There was a significant difference in the pre-test and post-test readings for blood pressure, heart rate, and temperature for all subjects. This significant increase in pre-test to post-test physiological parameters indicated that the physical output during the two, 30-second wall volley tests under each color condition was adequate to produce physiological parameter change.

The responses to the mini-questionnaire and questionnaire were combined due to the similarity in results. It was indicated that a majority of the subjects felt uncomfortable under the red lighting condition and that it created a warm atmosphere. In addition, over half of the subjects felt cooler under the blue lighting condition. Both of these results were compatible with the findings of Staples (1931), Birren (1961, 1970), and Schaie and Heiss (1964).

According to Staples and Birren (1961), after childhood the colors on the red end of the spectrum were least preferred and least liked by the subjects. The subjects' older ages in the current investigation could have had an impact on the negative reactions to the red color condition. Schaie and Heiss (1964) and Birren (1970) indicated that red was perceived by most individuals as being hot and blue as being cool. This was in agreement with the findings of this study. Although a high percentage of subjects felt uncomfortable under the red color condition, there was not a significant difference in performance under the various colored lighting conditions. Verbal and written comments elicited from the subjects indicated that there was a definite psychological reaction to the red and blue color condition. (See Appendix J for the subjects' comments.)

The subjects were not allowed to warm-up before each testing session, which may have had some effect on the subjects' wall volley performance. This factor in addition to the low number of subjects, especially those ranked as highly skilled, and the short amount of testing time in each session, could have been factors affecting the results of this investigation.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter contains a summary of the investigation, conclusions, and recommendations for further study.

Summary

The purpose of this investigation was to determine the effects of colored lighting conditions (blue, red, and white) on the variables of blood pressure, heart rate, and temperature on the performance of two groups of racquetball players.

A secondary purpose was to determine if the performance of Group 1 (highly skilled) and the performance of Group 2 (skilled) racquetball players differed significantly under the color conditions of blue, red, and white lights.

Additionally, the study examined the emotional perceptions of racquetball players relative to their performance under blue, red, and white lighting conditions.

On March 15, 16, and 17, 1982 on racquetball court numbers 19, 20, and 21 in Varsity Gymnasium at Appalachian State University, Boone, North Carolina, 19 subjects, one female and 18 males, completed a racquetball skills test. The subjects' ages ranged between 20 years and 4 months and 52 years and 4 months. The mean age of the subjects was 27 years and 11 months.

The subjects were selected from the leading players of the intramural racquetball competitions held at Appalachian State University. A total of four subjects were grouped as highly skilled and 15 subjects were grouped as skilled racquetball players. The highly skilled group was established according to the rankings of three racquetball authorities and if the subjects had been in the final four of an intramural racquetball open tournament in the preceeding years. The skilled group was determined according to the racquetball authorities and if the subjects had advanced at least three rounds in an intramural tournament. Subjects were tested utilizing a racquetball wall volley test under various colored lighting conditions (blue, red, and white).

The test consisted of the subjects sitting in the testing court for two minutes, then performing two, 30-second trials; one from behind the short line and the other from the long line marked on the floor 12 feet behind the short line. Pre-test and post-test readings for blood pressure, heart rate, and temperature were measured for each subject under each color condition.

At the end of each testing session, the subjects completed a mini-questionnaire concerned with feelings and reactions to the colored lighting condition that had just been completed. In addition, a comprehensive questionnaire at the completion of all the tests was also filled out by the subjects.

Prior to each testing session, all subjects were asked to complete an Emotional Outlook and Playing Checksheet. The checklist included questions dealing with the subjects' emotional status.

Statistical analysis indicated that there were no significant differences between the effects of color conditions (blue, red, and white) and blood pressure, heart rate, and temperature in Group 1 (highly skilled) and in Group 2 (skilled) racquetball players.

Analysis of data indicated that there were no significant differences between the effects of the color conditions (blue, red, and white) on the performance of the highly skilled and skilled groups. A significance of $F\ (1,17) = 8.29$,

$p < .05$ was found between the highly skilled and skilled racquetball players' performance.

The responses to the mini-questionnaire and questionnaire indicated that a majority of the subjects felt uncomfortable under the red lighting condition and warmer under this colored condition. The blue lighting created a cooler environment among the subjects.

Conclusions

Within the scope and limitations of this investigation, the following conclusions were warranted.

(1) Colored environments have no substantial effect on diastolic or systolic blood pressure.

(2) Colored environments have no substantial effect on heart rate.

(3) Colored environments have no substantial effect on temperature.

(4) Colored environments have no substantial effect on performance.

(5) Both highly skilled and skilled participants were not substantially affected by various colored environments.

Recommendations for Further Study

The following recommendations should be considered for possible future research investigations as to the effect of color, performance, and selected physiological parameters.

(1) A follow-up study should be conducted employing a larger sample size.

(2) Research should be conducted utilizing colors other than blue, red, and white and their effect on physiological parameters and performance.

(3) Research should be conducted allowing the subjects to spend a longer period of time under the influence of each of the color conditions.

(4) A similar study should be conducted, allowing proper warm-up before each color condition in order to enable the subjects to be ready for each testing session.

(5) A follow-up study should be conducted where better controls are placed on the physical activities of the subjects prior to the testing sessions.

(6) Research should be conducted which examines the effects of color conditions on various skill levels of various racquetball players.

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APPENDICES

Appendix A

Verbal Instructions for Wall Volley Test

Verbal Instructions for Wall Volley Test

Instructions:

You will be taking two, 30-second wall volley tests in each court. The first 30-second period will be a short volley test.

You must remain behind the short line (point out) to hit the ball. Begin by bouncing the ball on the ground and then hitting it with your racquet. You can hit the ball before it hits the ground or after it bounces several times. If you miss the ball or if the ball does not come back to you, you can retrieve the ball or use the one you have in your hand. If you lose both balls, the timer will give you one. You always have to start the ball by bouncing it first on the ground.

You will start with two balls.

Remember to stay behind the line.

The long volley will be the same except you must stay behind the line marked by the tape.

You are to finish one test and immediately begin the other.

Appendix B

Mini-Questionnaire

Mini-Questionnaire

1. Name ______________________________

2. Under what color condition did you just complete the racquetball wall volley test?

   Red ____________ Blue ______________ White ____________

3. Did you feel uncomfortable under this color condition?

   Yes ____________ No ____________

   Comments:

4. Did you feel physically hindered by the color condition?

   Yes ____________ No ____________

   Comments:

5. Did you feel emotionally or psychologically hindered by the color condition?

   Yes ____________ No ____________

   Comments:

6. Circle the day of testing.

   Tuesday Wednesday Thursday

Appendix C

Questionnaire

Questionnaire

1. Name ______________________________

2. Age: years ______________

   months ______________

Considering all the color conditions, answer the following:

	Red	Blue	White	No difference
3. Under which lighting condition did you feel most <u>comfortable</u>?				
4. Under which lighting condition did you feel most uncomfortable?				
5. Under which condition did you feel the warmest?				
6. Under which condition did you feel the coolest?				
7. Which condition caused you to perspire the most?				
8. Which condition caused you to fatigue faster?				
9. Under which condition did you perform the best?				
10. Under which condition did you perform the poorest?				

Comments:

Appendix D

Emotional Outlook and Playing Checksheet

Emotional Outlook and Playing Checksheet

Name____

1. Did any major negative happening occur in the last 24 hours? (Examples: failed a test; girl friend or boyfriend or spouse problems; physical problems; injuries, etc.)

   Yes __________________ No __________________

2. If yes, do you feel it is affecting your physical ability?

   Yes __________________ No __________________

3. If yes, do you feel it is affecting you emotionally?

   Yes __________________ No __________________

   Comments:

1. What color condition would you prefer to play racquetball under?

   Red ______ White ______ Blue ______ No Preference ________

2. What is your playing experience?

   __________years __________months

3. Are you color blind?

   Yes __________________ No _______________

Appendix E

Master Testing Score Sheet

MASTER TESTING SCORE

SUBJECT	Color Order	Pre-Temperature	Post-Temperature	Pre-Heart Rate	Post-Heart Rate	Pre-Diastolic	Post-Diastolic	Pre-Systolic	Post-Systolic	Performance		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												

Appendix F

Raw Data from Pre-test and Post-test Diastolic and Systolic Blood Pressure Measures

RAW DATA FROM PRE-TEST AND POST-TEST DIASTOLIC AND SYSTOLIC

BLOOD PRESSURE MEASURES

SUBJECTS	Pre-Diastolic	Post-Diastolic	Pre-Systolic	Post-Systolic	Pre-Diastolic	Post-Diastolic	Pre-Systolic	Post-Systolic	Pre-Diastolic	Post-Diastolic	Pre-Systolic	Post-Systolic
1	146	122	86	82	125	210	86	90	136	190	78	84
2	126	178	82	84	138	164	90	80	140	170	90	92
3	108	164	58	40	128	162	74	74	114	158	58	54
4	110	164	72	68	110	166	68	60	112	172	66	58
5	124	192	80	42	118	184	64	56	138	204	62	54
6	168	218	72	56	178	218	92	40	148	212	82	82
7	120	128	64	54	126	158	66	0	122	164	64	54
8	94	122	70	68	102	130	68	62	98	138	68	48
9	134	198	99	70	124	190	76	90	126	186	86	86
10	96	136	80	62	96	140	70	70	104	144	68	70
11	114	172	66	72	138	178	82	64	124	188	82	62
12	126	174	86	72	110	172	76	62	118	144	78	62
13	110	150	70	50	122	180	74	68	124	164	84	64
14	98	138	66	74	102	142	70	80	102	150	72	80
15	104	154	72	32	108	130	52	20	108	132	66	0
16	132	198	87	82	116	176	62	82	100	190	66	62
17	114	148	76	70	130	162	70	70	106	68	82	60
18	120	166	64	80	108	164	82	74	118	154	78	64
19	136	192	76	40	136	190	92	80	114	192	78	64

Appendix G

Raw Data from Pre-test and Post-test Heart Rate Measures

RAW DATA FROM PRE- AND POST- HEART RATE MEASURES

	WHITE		BLUE		RED	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
SUBJECTS	HEART RATE	HEART RATE	HEART RATE	HEART RATE	HEART RATE	HEART RATE
1	12	22	14	25	11	23
2	15	28	11	23	16	28
3	10	17	12	18	10	18
4	14	24	14	24	12	22
5	16	29	13	29	15	30
6	13	29	16	29	16	30
7	10	26	17	30	14	26
8	10	20	9	21	10	23
9	15	27	15	29	13	26
10	12	27	10	24	13	24
11	16	28	16	29	13	31
12	15	28	16	30	14	27
13	15	28	15	24	15	28
14	11	22	12	20	12	25
15	12	27	11	25	13	30
16	13	28	11	26	13	26
17	11	18	16	26	13	24
18	12	23	10	23	14	25
19	12	31	11	27	10	27

Appendix H

Raw Data from Pre-test and Post-test Temperature Measures

RAW DATA FROM PRE- AND POST- TEMPERATURE MEASURES

	WHITE		BLUE		RED	
SUBJECTS	Pre- TEMPERATURE	Post- TEMPERATURE	Pre- TEMPERATURE	Post- TEMPERATURE	Pre- TEMPERATURE	Post- TEMPERATURE
1	28.3	25.4	30.8	29.0	23.7	23.6
2	29.3	27.6	30.1	29.8	30.7	28.7
3	32.9	30.0	33.8	30.6	34.0	30.6
4	31.6	28.3	31.4	27.4	31.4	27.8
5	31.5	29.0	27.9	27.4	27.0	28.2
6	32.2	30.0	32.3	28.2	30.6	30.8
7	31.0	28.4	31.2	28.9	29.8	27.6
8	29.2	25.8	32.6	28.6	24.4	26.2
9	26.6	26.5	27.4	25.8	28.4	25.9
10	22.8	22.9	26.7	24.0	23.5	23.5
11	29.2	27.7	26.9	25.9	26.8	26.2
12	31.8	27.8	31.3	27.9	28.9	26.3
13	31.8	29.8	33.0	30.1	31.6	23.3
14	32.1	30.5	32.1	26.6	32.9	29.7
15	32.0	29.0	28.9	27.0	31.8	31.3
16	23.5	24.3	24.3	24.7	25.7	24.3
17	31.4	27.5	32.3	26.0	32.9	29.9
18	25.4	26.3	25.8	25.3	29.6	24.5
19	28.1	26.8	25.3	23.9	29.1	25.8

Appendix I

Raw Data from Summation of Short and

Long Wall Volley Test Scores

RAW DATA FROM SUMMATION OF SHORT AND

LONG WALL VOLLEY TEST SCORES

SUBJECTS	WHITE	BLUE	RED
1	42	45	43
2	44	43	49
3	36	33	35
4	32	35	31
5	30	37	29
6	42	46	40
7	34	40	38
8	34	29	29
9	36	27	40
10	32	31	38
11	38	37	39
12	31	43	35
13	34	43	41
14	23	29	35
15	35	26	26
16	41	43	33
17	44	39	42
18	39	48	43
19	51	42	50

Appendix J

Comments on Questionnaire

Comments on Questionnaire

Several subjects offered additional comments that were beneficial in the consideration of the effects of lighting during the testing procedures.

"I felt that the effects of the lights were more mental than anything. I felt I tried harder under the new colors than I did under the normal white color."

"I felt closed in in the red environment."

"I loved the blue court."

"The red court felt darker than the white and blue."

"Could not see as well under the blue and red as under the white."

"The blue court was cosmic."

"The blue court was relaxing and cool."

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