HUE DISCRIMINATION AS RELATED TO EYE COLOR AND COLOR EDUCATION: AN EXPLORATORY STUDY

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PREFACE

This exploratory study was undertaken to develop an understanding of the relationship between the physiological aspects of the eye, color education, and the ability of the eye to discriminate color. The objective of the study was to analyze whether a relationship exists among eye color, levels of color education, and major course of study and the ability to discriminate hues.

Of the three different eye colors studied in this research, the largest variability in hue discrimination appeared to be students with green eyes. Those students with green eyes in landscape architecture appeared to score better (lower) in the green-yellow area of the spectrum than any of the other majors and eye colors. However, students majoring in interior design with green eyes scored highest of any of the groups, indicating less ability to discriminate among the hues. Possibly, the concentration of work with the green palette by landscape students could account for lower scores than other groups.

The format of this dissertation deviates from the general thesis style used at Oklahoma State University. The purpose of this deviation style is to provide manuscripts suitable for publication as well as to fulfill the traditional thesis requirements. The first three chapters of the dissertation and the two manuscripts were written using the Publication Manual of the American Psychological Association. The manuscripts were written in journal style for submission to Home Economics Research Journal and Journal of Interior Design Education and Research. In addition, the content of the research requires the use of colored visuals in the understanding of the content. The cooperation of The Graduate College and Dean Norman Durham in these stylistic changes is greatly appreciated.

Grateful appreciation is acknowledged to those individuals whose guidance and support have helped in the completion of this research. My deepest appreciation to Dr. Margaret Weber, who has served as my advisor through the last portion of this process. I am indebted for her patience and support through the stages of the completion of my doctoral studies. A special thanks and appreciation is extended to Dr. Larry Claypool, for his guidance in analysis of the data. I am also greatly appreciative of Dr. John Gardiner who, as the only remaining member of my original committee, has offered encouragement and support for the completion of this degree. I would also like to acknowledge Dr. Elaine Jorgenson, Dr. Sue Williams, and Dr. Larry Hochhaus for willingly becoming committee members so late in the doctoral process.

Many others have contributed to the completion of this study. I am grateful to the interior design faculty and graduate students in the Department of Housing, Interior Design, and Consumer Studies who have shared their time, laughter, friendship, and encouragement.

Most of all, my greatest appreciation and deepest love goes to my family and friends who have encouraged, supported, and endured this process with me. My special thanks to my brothers Bill and Duane, and my friend Kathy, for their encouragement and shoulders when I've needed them. My parents, Mr. and Mrs. Nick Evans, have my greatest love and appreciation for their unceasing support in this endeavor and throughout my life.

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CHAPTER I

INTRODUCTION

Color! The word immediately brings thoughts of varied and different sensations to the minds of individuals. It has long been known that humans have strong likes and dislikes to the colors that surround them. Those colors, that vary through innumerable shades, tints, and tones of hues, have been categorized by a multitude of theorists throughout history. However, the humans' psychological views of colors can be as broad as those color ranges and theories.

It is hard to imagine the world without color. The environment would be limited to black, white, and values of grey. Humans, however, are endowed with the ability to distinguish the many hues in their surroundings. Physiological differences between the human eye and the eyes of other animals enable this to occur. Those differences, which will be discussed later, have enabled the human to provide not only aesthetic pleasures to the near environment but also have allowed the human to provide for security in the environment.

Color is a much studied but still highly undefined phenomena. The avenues of study and theory development include psychological, physiological, chemical, and the aesthetic. The problem that arises from these many areas of study is that they are all so interconnected that a researcher can rarely study one aspect without relating it to another. Color perception, one of the many topics of study, is not only a complex biological and psychological process but in numerous ways not fully understood. In the fields of design all of these aspects of study are utilized to create more pleasing environments. To create these environments and utilize the many aspects of color, designers, whether interior or exterior must depend on knowledge gained through physical abilities, education, and working experience.

The investigation of color as an integral part of the environment has been limited. Acking and Kuller (1972) classify the study of color into two groups: (1) color preference and (2) the physiological effects of color and colored light. The authors divide an individual's total perception of surroundings into certain factors; (1) a feeling of comfort and security, (2) estimation of social status, (3) description of appearance of space and light, (4) the intensity or complexity of their environment, and last (5) the unity of the environment. They, however, fail to address the question of physiology and the environment.

The need to address how environmental specialists, such as architects, interior designers, artists, and landscape architects, visualize and perceive the surroundings becomes a paramount and important task. If the physical differences of each human can be measured and judged, then it is important that an understanding be reached of how color and design judgments are made by individuals with differing hue discrimination abilities.

When the discussion of color is approached the differences of what one human sees, for example blue, and what another human sees is not necessarily the same. Or possibly the color is not the same blue he or she might see at a later date and time. Therefore, each of us lives in our own private sensory world.

Humans trying to explain what each of them experiences, have developed a vocabulary based on aspects of light and pigment color theory. This vocabulary is also closely related to objects and conditions that are found in the near environment. For example, an individual might describe the color of a new car as sky blue or forest green. Using words that one believes can help communicate to others a color that is constant or that is easily identifiable. But how constant is that color? Does sky blue mean a pale blue, a greyed blue, or a bright blue-green? With changes in the parameters of color, it has been noted that color can be perceived but not totally described, simply because humans rely on their individual experiences and abilities.

A human being is a very complex organism that shares the majority of the same body functions and mechanisms with the rest of the world population. However, small differences in the individual human body are what make each one special and interesting. Hair color, body shape and size, voice timbre, skills, and abilities are but a few human variations that occur to create a one-of-a-kind work of art. One of the most descriptive of those variances is eye color. Genetically determined by the mother and father, eye color variations are a broad spectrum taking into account the tints, shades, and tones that can occur within that realm of eye color. But the color of the eyes is only the most obvious characteristic of a complex organ. The eye is a mechanism that helps the human learn, appreciate, and function in the everyday world. Does the difference in the physiology of the eye create variations in how the eye functions?

Throughout a human life the learning process involves both regimented learning and learning through life experience. As a child, one is taught that an apple is red or the sky is blue by either a parent or other care giver by simply saying that the apple is red or the sky is blue. Later in the formalized educational setting of the classroom a youngster learns ideas through reading and by sharing other individual's experiences. More complex ideas can be incorporated into the store of knowledge later in their lives by continued readings of more complex theories or by utilizing colored materials and media in day to day activities. Materials and media such as paint, light, paper, fibers/fabrics, building and plant materials, are some of the typical materials used by designers in the creation of environments. If a student is exposed to color training by either reading about theories or by the manipulation of environmental materials is there a difference in their ability to recognize change in hue, value or intensity of color? If it is believed that physical properties affect the light reception and thereby the visual perception then the iris must play a role in that interpretation process.

Purposes and Objectives

Research has not approached the question of visual color perception based on human physical traits and the color education experiences of individuals. This exploratory study was conducted in response to the need for more research in the area of hue discrimination and the physiological and educational differences of individuals. The purposes of exploratory research generally fall into three categories; (1) the desire for better understanding of a research topic, (2) to test the feasibility of undertaking a more experimental study, and (3) to develop the methods to be employed in a more focused study. Exploratory studies are valuable to social science research because they are "essential whenever a researcher is breaking new ground, and... can almost always yield new insights into a topic for research" (Babbie, 1986, p.73).

The purpose of this study was to examine differences in hue discrimination among individuals. Criteria used to assess those differences included the variables of eye color and color education. Eye color variations were restricted to those individuals with blue, green, or brown eye coloration. Levels of color education were assessed with hue discrimination. The academic course of study or major was limited to the aesthetic programs of art, architecture, landscape architecture, and interior design.

The following objectives were used to guide the study.

1. To assess whether there were differences in hue discrimination among individuals majoring in art, architecture, interior design, and landscape architecture.

2. To assess whether there were differences in hue discrimination between individuals with high and low levels of color education.

3. To assess whether there were differences in hue discrimination among individuals with blue, brown, or green eyes.

4. To analyze whether a relationship exists among eye color, levels of color education, and major course of study and the ability to discriminate hues.

Limitations

The findings and conclusions in this exploratory study were limited by:

1. The sample or population of art, architecture, interior design, and landscape architecture majors were limited to those students enrolled at Oklahoma State

University during the study period.

2. The study was also limited by those courses offered in the respective curricula of each major and by the written description of each course in the Oklahoma State University Catalog.

3. The loss of sample due to unrecognized eye color such as grey and hazel also limited this study.

4. Limiting the research study was the self judgment of eye color based on the Driver's License Bureau procedure for noting an individual's personal eye coloring.

5. An additional limitation of this study was the five year interval in sampling and data collection.

Assumptions

This study was guided by the following assumptions:

1. It was assumed that all course descriptions from the course catalog and used in the demographic questionnaire were indicative of what was taught in each individual course and that there was no change in the curriculum.

2. It was also assumed that the recorded eye color on the drivers' licenses were the correct color for each individual subject.

3. It was assumed that a student's understanding of color increased in relationship to the enrollment in color courses.

Operational Definitions

The following definitions were given to better understand and to operationalize this study.

1. Hue discrimination was defined as the ability to visually distinguish minor changes in color in a full hue spectrum range.

2. Eye color was defined as the iris color of an individual. Those colors selected for this study were blue, green, and brown. The process of defining an individual's eye color was determined by the use of a valid driver's license.

3. Color education was defined as selected, academic coursework with color content completed while enrolled at Oklahoma State University. Low levels of color education were defined as those individuals that had earned 0-18 credit hours in courses having color content. High levels of color education were defined as those individuals that had earned 19 or more credits in courses having color content.

4. Major was defined by those matriculating students enrolled as declared majors in the academic programs of architecture, landscape architecture, interior design, and art at Oklahoma State University.

Summary

Color, in summation, is a very complex issue that has been studied in numerous contexts. Little research has been conducted, however, concerning the perception and discrimination of color by aestheticly educated individuals. This exploratory study was directed toward researching the area of study concerning descriptive and physiological eye differences that have largely been ignored in color research. The purpose of this study was to evaluate and describe those differences in hue discrimination that occur among individuals with blue, green, and brown eyes that have had either high or low levels of color education and are majoring in architecture, landscape architecture, interior design, or art.

CHAPTER II

REVIEW OF LITERATURE

Physiology of the Eye

In Human Color Perception: A Critical Study of the Experimental Foundation Sheppard states that "the very concept of color sensation is devoid of meaning except in a perceptual (i.e., cortical) sense" (Sheppard, 1968, p.3). The author believes that only by including any appropriate cortical hypotheses with any other hypotheses, can any theory be developed that will describe "with any reasonable success the changeable aspects of human color vision" (Sheppard, 1968, p.3).

The perception of hue, what the human sees and defines as a color, is an individually based process. The actual color that will be seen by the eye depends on a series of factors, internal as well as external, which are linked together in a rather complex chain, some parts of which are more difficult to trace than others owing to the limitations of our knowledge (Southall, 1937). Theories and views on eye physiology and color perception developed in the last century are still recognized and generally accepted (Haapasalo, 1982).

Included in the study of color is the understanding of three basic disciplines; physics, physiology and psychology. According to Ralph Evans (1974) the complete subject of color divides into the physical causes "that produce the relatively simple final stimulus and the complex physiological and psychological reactions to this stimulus that produce the perception of color" (Evans, 1974, p.11). The interaction of these three disciplines is so connected that one cannot be left unexamined without neglecting some meaningful portion of color research. Trying to decide which one of these areas of color research to begin with in gaining an understanding of color is somewhat like deciding what came first, the chicken or the egg. It is probably best, however, to begin with a physiological viewpoint because the human body serves not only as the receptor but also as the translator of the energy that becomes the concept known as color.

The eye serves as the initial step in the perception process. "The eye is an organ of more or less spherical shape; the sphere of about 12 mm. radius, has a transparent protuberance, towards the front, of greater convexity 8 mm radius..." (Wright, 1964, p.47). This spherical shape is preserved by an envelope that consists of an opaque sclerotic or white of the eye and the cornea, which forms the protuberance. The white of the eye is pierced at the back by the optic nerve which connects the retina to the brain (Wright, 1964).

The choroid, a nutrient membrane, is attached to the inner surface of this shape preserving envelope and acts as an absorbing material for unwanted rays (Wright, 1964). In the front of the choroid is attached the ciliary body, a muscular organ, which plays an important part of the focusing process. The ciliary extends to the iris which has an opening of variable diameter known as the pupil (Wright, 1964).

The structure of the iris constitutes the front outer layer of the spherical form and the anterior surface of the iris is in contact with the aqueous humor. The iris functions as the major determinant of the amount of light entering the eye (Padgham & Saunders, 1975). Irises, acting as variable apertures that open and close, monitor the intensity of light changes in the environment for the eye. Constructed of colored fibrous material, it surrounds the central aperture called the pupil. "The iris behaves as a diaphragm, modifying the amount of light entering the eye, whilst the ciliary body contains muscle fibres which, on contraction, increase the refractive power of the lens (accommodation)" (Dawson, 1963, p.1). Ralph Evans believes that the iris plays little part in the act of color perception except in the modification of lens aberrations (Evans, p.15). However, it must be remembered that the eye acts as a receptor and according to George Palmer all receptors and reception systems may differ and affect the total visual and color perception. Guild states that "the classification of receptors into different types is perfectly definite and depends solely on those physical properties of receptors which determine their relative sensitivity to radiation of different wavelengths" (MacAdam, p.199, 1980).

Two muscles act as the contracting and dilating controllers of the central pupil. The amount of variation in the opening in the pupil ranges from 2 mm to 8 mm, thereby controlling the amount of light entering the eye and the amount of light falling on the retinal portion of the eye (Padgham & Saunders, 1975). The aperture's size is determined by the amount and quality of light reaching the retina rather than the illumination which strikes the outer portion of the eye (Padgham & Saunders, 1975).

The cornea, ocular media and the lens constitute the focusing unit of the eye. The cornea is a transparent membrane which covers the protuberance at the front of the spherical shaped eye. Directly behind the cornea is an area filled with a gelatinous material composed of 99 percent water plus salts and proteins called the aqueous humour.

The lens is the principal medium that affects the distribution of the incident visible light, that is, the light that falls directly on the eye. A soft bi-convex structure, the lens is enclosed in a sheath or capsule and is attached to the ciliary body by the zonule. The internal structure is made up of layers which fit together similarly to an onion; layers consisting of the central embryonic nucleus, the adult nucleus and the outer shell. As the human ages the lens "yellows" and in turn increases the absorption in the blue region of the visible spectrum (Evans, 1974).

The lens, located behind the aqueous humour, is supported from behind with another transparent gelatinous material called the vitreous humour. This mass also consisting mainly of water constitutes the major portion of the eye (Padgham & Saunders, 1975). The vitreous body represents 5 cc of the total 7 cc or 8 cc volume of the eye. The jelly-like substance is held together by a membrane called the hyaloid. The hyaloid also adheres the vitreous substance to the retina. The lens adjoins the rear surface of the iris (Wright, 1964).

The inside of the rear portion of the choroid is covered by the retina. Until the sixteenth century it was thought that the lens was the main component in producing an image and translating that image to the brain. However, in 1866, Schultz identified two types of receptors located in the retina of a variety of animal eyes that are now accepted as mediating the visual response (Padgham & Saunders, 1975). These two type of receptors located throughout the retina are known as rods and cones.

The distribution of the rods and cones through the retina varies both in their location and density from one area to another. The highest concentration of rods are located around the periphery of the retina. Cones on the other hand, are at their highest concentration in the center of the retina referred to as the fovea.

There exists in the human visual sense, a range of vision based on a conical area measured from a horizontal stare. This conical shape, which approximates 60-70 degrees from horizontal in all directions; up, down, left and right, is referred to as the cone of vision. The rods and cones located in the retina are fundamental in translating what the human sees in this cone of vision.

The rods and the cones differ in their ability to translate light energy into images. The difference is due to a photosensitive pigment known as rhodopsin and is easily affected by light causing it to 'bleach'. The rods are sensitive to any movement or to mass that occurs in peripheral areas of the cone of vision. This type of vision is referred to as peripheral vision. Because the rods are not sensitive to color interpretation, this type of vision is mainly used as a warning type of vision process that can be effective in low light situations. Vision at these low light levels is referred to as scotopic.

The cones on the other hand are used primarily for the interpretation of fine acuity and color vision. In the central portion of the retina where the cones are the most concentrated, the fovea, there exists a difference in the ability of color interpretation. "Even within the fovea there are significant differences, as revealed, for example, by the threshold sensitivity to light of different wavelengths" (Wright, 1964, p.50). As intensity levels increase beyond scotopic, color vision begins to become effective. At a certain level both mechcanisims, rods and cones, respond and produce mesopic vision. At even higher levels of light tolerance, where color perception is fully developed, the vision is said to be photopic in nature. At this vision level it is thought that the less developed scotopic vision is either not functioning or in abeyance (Evans, 1974).

"The perception of colour necessarily implies the structures (of the eye) processes must exist which are capable of reacting differently according to the wavelength of incident light" (Wright, 1964, p.38). There is existing theory that the receptors in the eyes, rods and cones, are specialized in the interpretation of a particular radiation. According to Wright there is reason to believe that there exists three types of cone receptors which process the whole gamut of color sensations.

Originally this theory came from Thomas Young in 1802 and was supported by Hermann von Helmholtz 50 years later in 1852. Young theorized that only three radiations, red, violet (blue), and green were analyzed by the eye and signaled to the brain by these specialized cone receptors (Phadgham & Saunders, 1975). "Each nerve acts, not, as some have thought, by conveying to the mind the knowledge of the length of an undulation of light, or of its periodic time, but simply by being more or less affected by the rays which fall on it" (Evans, 1974, p.69).

Young theorized that when a derivation of hue such as magenta was "seen" that more than one (red and violet) of the cones were stimulated simultaneously and resulted in a mixing of the sensations in the correct proportions. This mixing theoretically, resulted in the color that is known as magenta. When all of the three types of cone receptors are stimulated equally the resultant outcome is white (Padgham & Saunders, 1975).

One simplistic possibility in assuming this type of mechanism behavior is that each of the cone receptors secrete three different photochemical substances. This in effect creating multiple variations of color responses (Wright, 1964). According to Sheppard there is still no definite experimental evidence of three and only three specific selective photochemicals (Sheppard, 1968).

"The pupil of the eye and the adaption of the retina are the only internal factors of the visual sense which are controlled by external means" (Luckiesh, 1944, p.53). Adaption is affected by the brightness in the visual field. Fundamental to the understanding of the working of the eye, adaption is described by Southall (1937) as follows:

> Accordingly we speak of the adaption of the eye...and say that it is bright-adapted in daylight vision and dark-adapted in twilight vision; making a distinction between the photopic (bright-adapted) eye and the scotopic (dark-adapted) eye. (p.299)

Varying environmental light will affect not only the eye structures operation but will also affect it's ability to process the information. During the first few minutes of dark adaption, the cones are more sensitive than the rods, with the rods taking over later (Haber, 1968, and Haber & Hershenson, 1973). "Looking alternately from brighter to darker areas reduces the efficiency of vision" (Luckiesh, 1944, p.53). In 1973 Florip and Bauer studied the dark adaption of the eye after exposures to single pulses of light. The illuminances were measured at the subject's face and the duration of the illumination ranged from .01 second and 1.0 second. Angle of incidence, 30 degrees, was restricted by asking the subject to look straight ahead before the pulse of light. Control of recovery was given to the subject by their ability to adjust an adaptometer. The results of the study indicated an increase in recovery time as the flash duration and illuminance increased. This supports Lukiesh's statement on the efficiency of the eye after adaption.

Local adaption can also exist as a condition where areas of the eye simultaneously have different degrees of adaption in different zones of the visual field (Hering, 1964). Pirrene states in <u>Vision and the Eye</u> that "quantitatively, if not qualitatively, the laws of colour mixture are found to be different in different parts of the fovea" (Pirrene, 1967, p.299). The processing of the light by the eye to transmit that into a color interpretation will vary from individual to individual.

The pupil is subject to slight, but important control of the visual sense. However, it is more important as the one part of the entire visible sense affected by external factors. It also seems to be influenced by certain internal results of seeing (Luckiesh, 1944). Records of it's size under various conditions, such as brightness, and of the internal factors, such as fatigue, promise to aid in understanding seeing and the results of this activity upon human beings (Luckiesh, 1944).

Physiologist Ewald Hering proposed, unlike the Helmholtz theory, that there were three pairs of color processes. These consist of a black-white theory, a red-green process and a yellow-blue process. This theory. an opponent process theory, is based on an antagonistic relationship between each pair. This relationship means that a color can have some red or some green but cannot have both red and green in the same place at the same time. In turn, the receptors can signal the brain either red or green but not both at once (Bornstein & Marks, 1982).

Support of this theory is reiterated by Jameson and Hurvich's research at the University of Pennsylvania. Establishing that the eye does contain three receptors but the pattern of activity fed to the nerve cells by these receptors is the underlying factor to the experience of color (Hardin, 1988, and Jameson and Hurvich, 1955, 1956).

Light and Color

"Out of the whole gamut of electromagnetic radiations from gamma rays to radio rays, only a small band of radiation is capable of stimulating the eye" (Wright, 1964, p.1). If one compares the quality of visual sensation with the actual physical composition of light, that which we know of the light producing elements, then an individual can draw certain broad generalizations from one of those elements to the other (Wright, 1964).

Light is regarded generally as a physical phenomena that results from various amounts of energy being transmitted from a source at a given speed at various frequencies. The visible spectrum, the energy that the human can see, is a very small portion of the total energy emitted in the atmosphere.

The nature of color was first discovered by Sir Isaac Newton when his experiments with light and a prism produced, on a white sheet of paper, a colored spectrum band. He was convinced that all of the spectrum of colors were present in the original white light and not introduced by the prism. Newton sought to prove this theory by utilizing a second prism directly after the first so that light passed through the first prism, was refracted again through the second and on to a white sheet of paper. The results proved that the colored band could not be refracted further. He surmised from this study that white light was a composite mixture of different kinds of rays (Padgham & Saunders, 1975).

Wright quotes from Newton's notes that "the Spectrum did appear tinged with the Series of Colours, violet, indigo, blue, green, yellow, orange, red together with all their intermediate Degrees in a continual Succession perpetually varying. So that there appeared as many Degrees of Colours, as there were sorts of Rays differing in Refrangibility" (Wright, 1967, p.1).

The hue is determined by the position in the spectrum of the radiations which are markedly stronger than the remainder. The saturation or intensity is determined by the degree to which those radiations predominate over the others (Wright, 1964).

According to Houston's <u>Vision and Color Vision</u> the perception of indigo would be peculiar to certain subjects otherwise perfectly normal. "While most observers only perceive a gradual transition from blue to violet, some, like Newton, distinguish a particular dark blue which differs in appearance from both blue and violet" (Wright, 1967).

Variations in the transmission of light through the optical media; cornea, lens, vitreous and aqueous humours, must be taken in order to evaluate color. "Account must first be taken of the light reflected by the surface of the cornea (which gives rise to the Purkinje images)" (Wright, 1967, p.87). According to Wright (1967), Purkinje images are the reflection of light off of the blood vessels in the cornea.

Munsell Color Theory

To better understand the literature of the many avenues of color study, it is necessary to define terms that regularly occur. Many of these terms are found in all areas of color study and some are used only in specific areas. These definitions are to better facilitate the reading of the following information and are based on Albert Munsell's Color System. This system has been recognized internationally for its precise identification process and is used frequently in research.

First, it must be noted that color, as stated previously, is a highly complex area of study. The first concern that needs to be addressed and defined is the area of the descriptive process.

Several terms come to mind in the description of color. Terms such as hue, value, chroma to name but a few are commonly used by both professionals and lay persons. According to the Munsell Color Theory many of these terms can be identified and defined.

First consider the term hue. Not often used but very important to exploring the different dimensions of color, the term hue is used to describe the area of the wavelengths that are reflected from an object to produce a specific color. The term color is often liberally exchanged for the term hue (Munsell, 1929).

Hue is often referred to as the first of the three dimensions of color. Munsell, as well as many other theorists, likens this dimension to a circle or wheel of the varying hues arranged in modulating order of their occurrence in light theory. Munsell theorizes that there are 10 such pure hues. There are 5 principal hues; red, yellow, green, blue, and purple. There are also 5 intermediate hues; yellow-red, green-yellow, blue-green, purple-blue, and red-purple (Munsell, 1929). Each of these 10 hues is identified by an alphabetical notation consisting of the first letter of each hue name; red R, yellow-red YR, yellow Y, green-yellow GY, green G, blue-green BG, blue B, purple-blue PB, purple P, red-purple RP (Munsell, 1929).

Munsell incorporates into the theory a notation system that enables each hue with all variations to be exactly identified. The first notation designation is the identification of the 5 principal and 5 intermediate hues. Each one of these pure hues is designated with the number 5. However, each one of the hues has a hue identification range from 1 through 10 with the number 5 always representing the pure hue (Munsell, 1929).

To better illustrate this hue notation, Figure 1 indicates the clockwise arrangement of the principal hues and their numerical notation. Figure 2 removes a portion of the color wheel to further illustrate how each hue has 10 variations in itself. It is important to note that the number 5 always denotes what Munsell has determined to be a principal hue and that any other number that precedes a hue alphabetical notation, such as 7 YR, indicates a variance

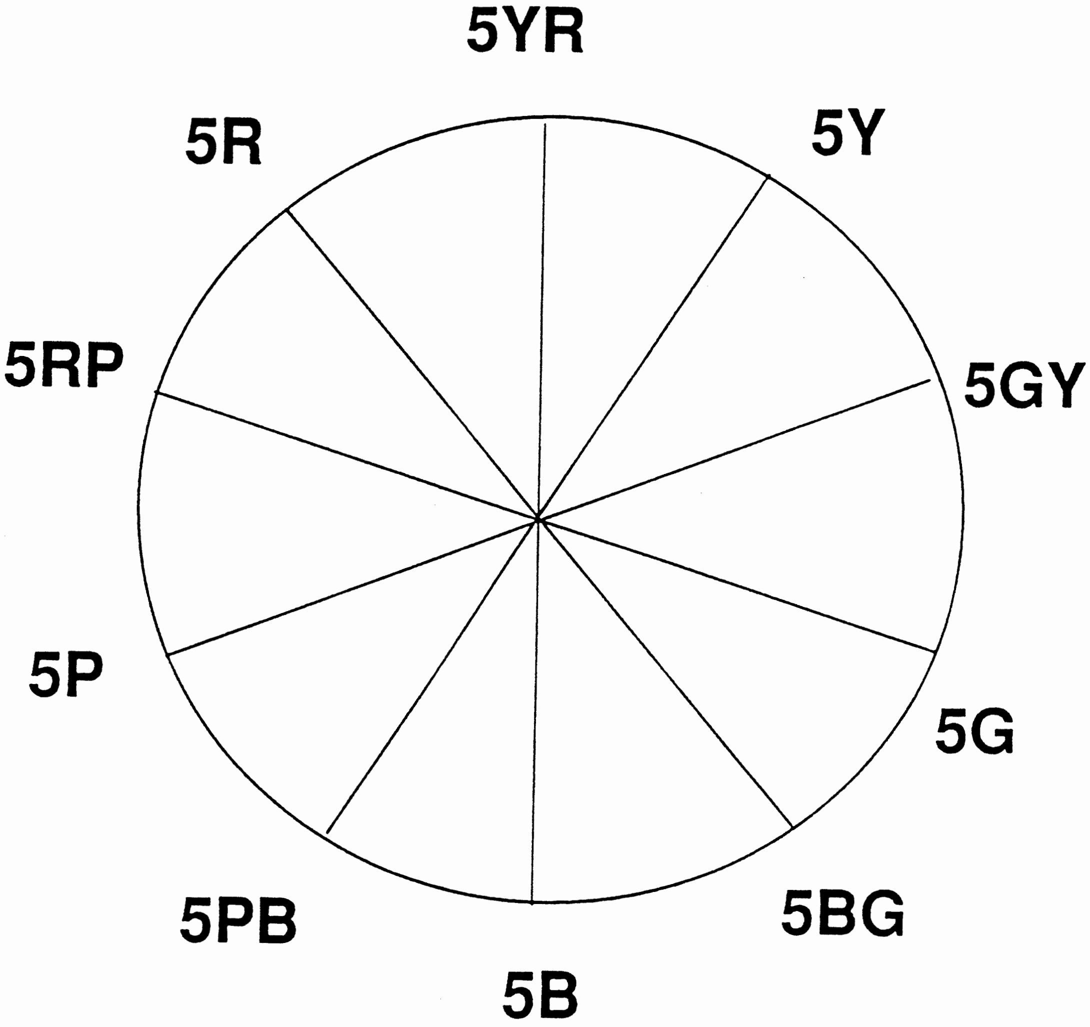


Figure 1. Munsell Color Wheel Illustrating the Hue Notation System.

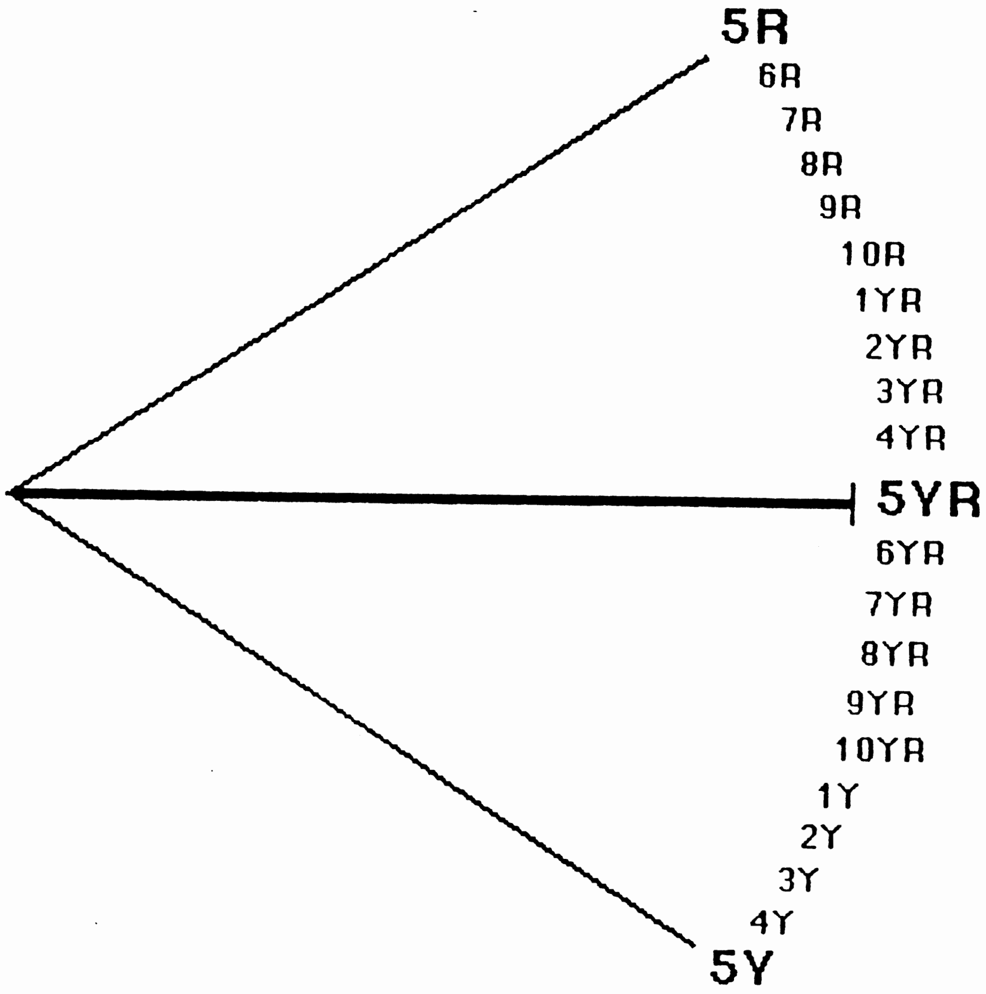


Figure 2. Selected Portion of Munsell Color Wheel Illustrating Numerical Notation of 1 through 10 for a Single Hue.

from the principal hue (Munsell, 1929).

Because the Munsell notation system is based on tens, variations in hue can also be calculated in decimals to exacting measures. For example, the hue 6.548Y can exist and be calculated in the Munsell system. The hue, 6.548Y, would be a slight variation from the pure hue of yellow and would be moving in a clockwise direction toward green-yellow (see Figure 3) (Munsell, 1929).

The second term often found in color study is that of value. Value refers to the second dimension of color. The second dimension being the lightness or darkness of a hue. Again referring to Munsell's graphic demonstration of the dimensions of color, Figure 4, value is seen as the vertical movement of color, that is, how value (lightness or darkness) changes as we go up or down the center axis. Munsell prescribes the center axis as a value scale with pure black located at the bottom represented by a numerical designation of 0. Pure white is located at the top of the axis and is given a numerical notation of 10. Variations of grey numerically progressing from the black (0) to the white (10) compose the remainder of the central axis of the Munsell color solid. These black, white and greys combine to form what is referred to as the value scale (Munsell, 1929).

Each hue of the color wheel can have variations in value. For example, red can be lighter in value such as indicated by the descriptive word pink or it can be darker

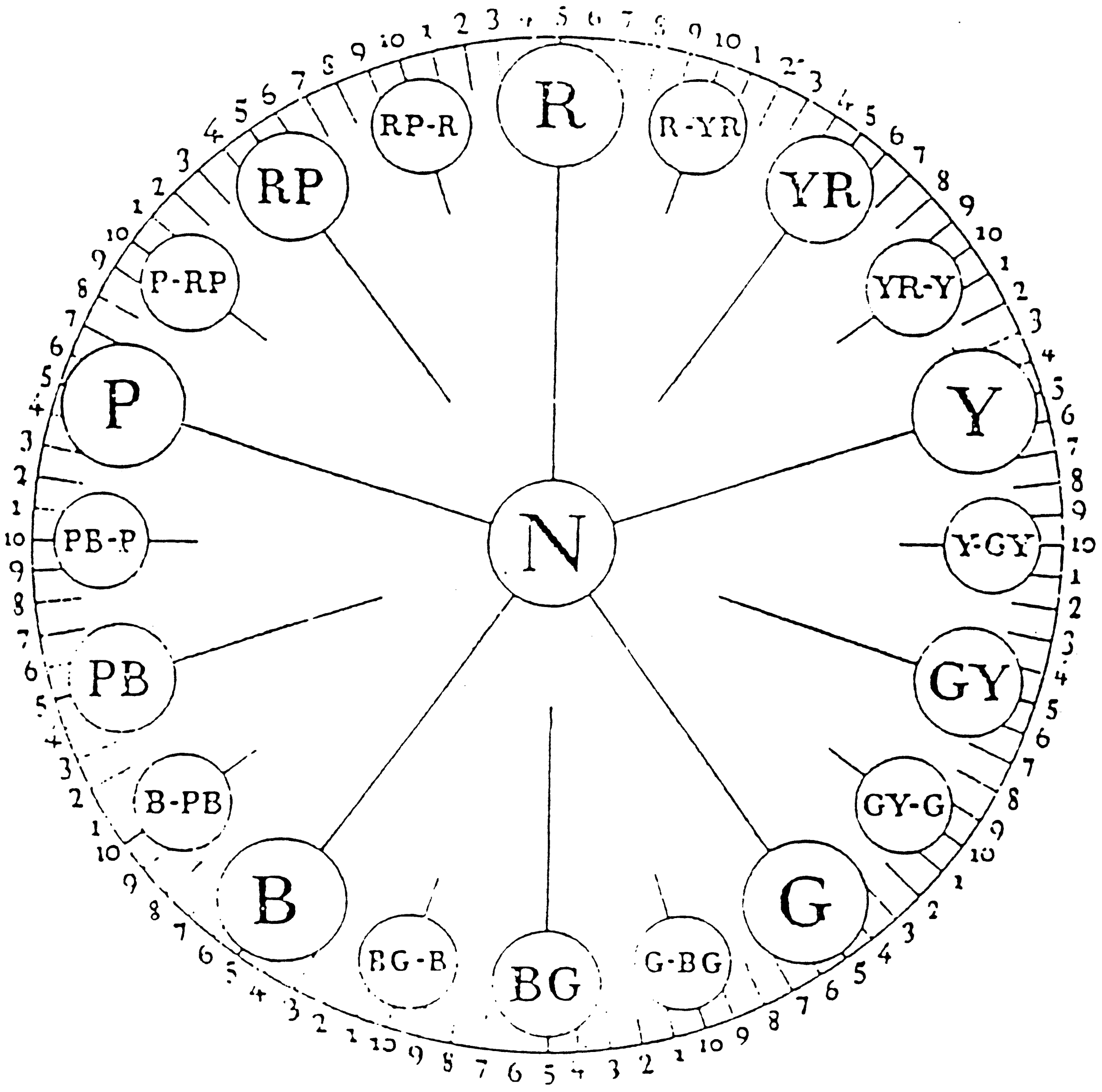


Figure 3. Numerical Notation of Munsell Color Wheel Illustrating the Decimal Capabilities.

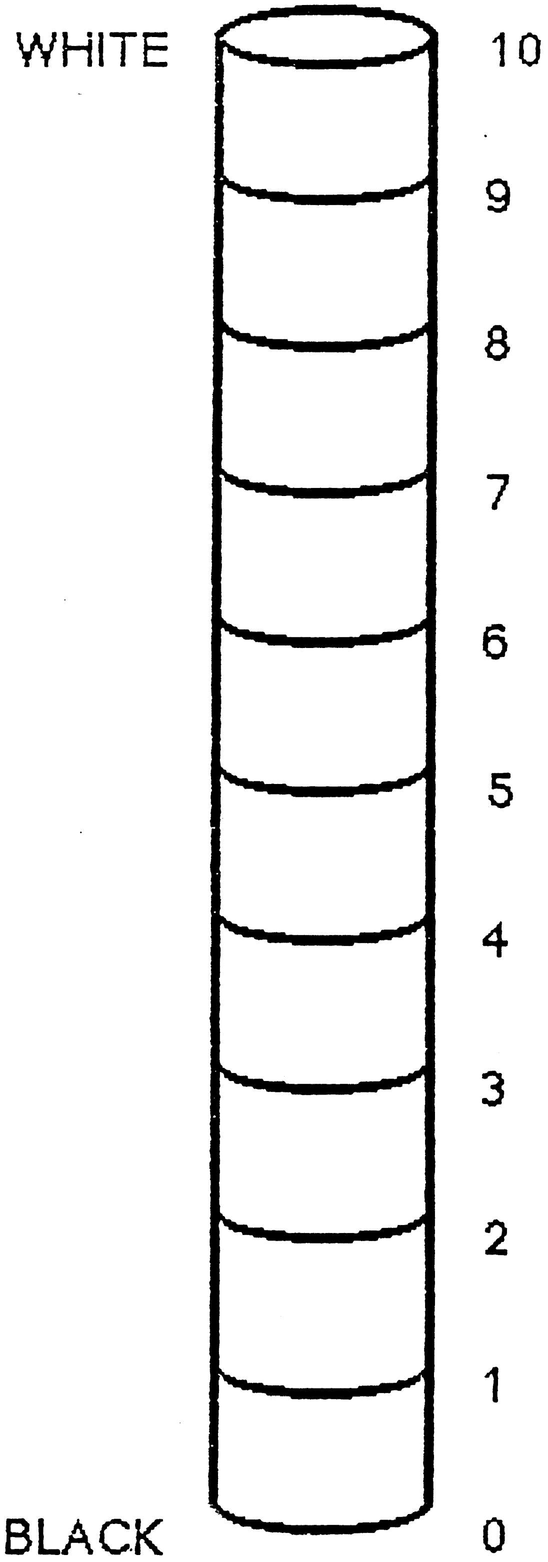


Figure 4. Center Value Axis of Munsell Color System.

in value such as indicated by the word burgundy. Two things must be understood when there is a change in the value of a hue. First, when a change in value takes place the numerical notation of the Munsell system indicates that change. A value notation that is a high number, such as an 8 indicates a value that is lighter and closer to the white end (10) of the value scale. The same holds true when the value notation is lower or closer to black (0) such as a 2. The pink color that was previously noted would fall somewhere at the top of the value scale and the burgundy would be found closer to the bottom of the scale. The value notation follows a slash immediately after the hue notation. For example, the pink might be noted as 5R/9 (Munsell, 1929).

The second thing that must be noted about value is that every pure hue has in itself a natural value. Yellow is by nature a light value and purple is by nature a dark value. Therefore, each of the principal hues will naturally exist on the outer ring of the color solid at a different level. Figure 5 illustrates the levels at which each of the principal hues is located. Yellow has a natural value of 8 and purple has a natural value of 4 (Munsell, 1929).

It must be remembered that the words that are used in layman's everyday terminology are just that, layman's terms. Every term produces a different connotation to each individual. The words pink and burgundy are simply terms that designate a variation in hue, value, and also chroma

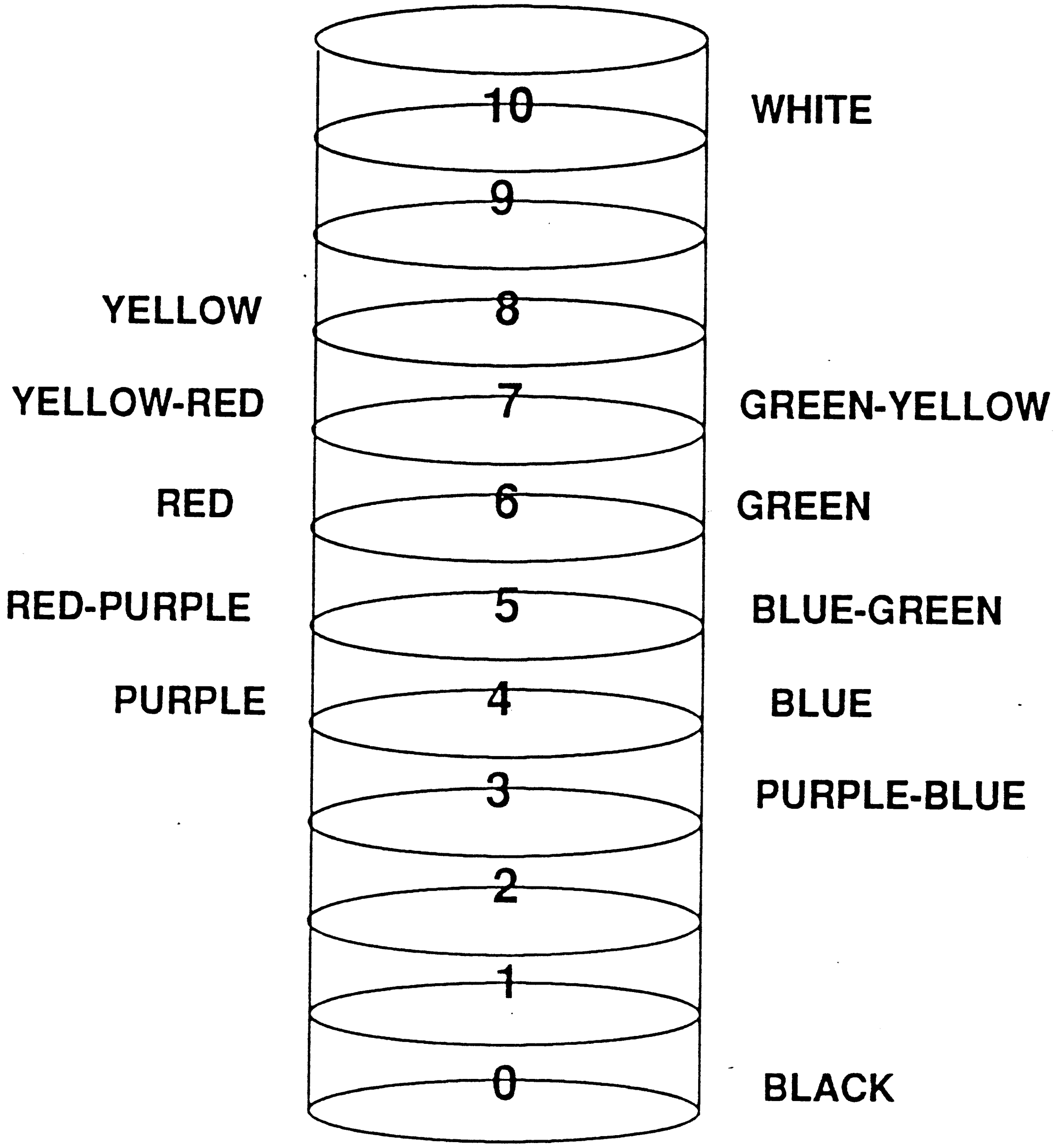


Figure 5. Natural Value Level of Hues on Munsell Color System.

(to be addressed later). There are however, two words that are used by both laymen and theorists to describe those changes in value. The word tint is used to indicate a color that has been lightened. The word shade is the term used to indicate when a hue has been darkened. Therefore, pink would be a tint and burgundy would be a shade. The process by which these hues are changed in value will be discussed later (Munsell, 1929).

The third and last dimension of color is that of chroma. The terms intensity and saturation are also used when describing this dimension. The terms refer to the brightness or dullness of the hue. According to Munsell each hue naturally exists in it's brightest chroma. Munsell's color solid reflects chroma and variances by placing the highest or brightest chroma on the outer peripheral edges of the solid. Changes in the chroma, dulling of a hue or neutralizing of a hue, is indicated by moving closer to the center axis. When a hue has been dulled to its extreme it is close to becoming grey but still contains a fraction of the original hue (Munsell, 1929).

As with a natural value, all pure hues also exist with a natural chroma. Therefore, all pure hues will maintain a different distance from the central axis. Some, such as yellow will be farther from the central axis than purple which is naturally duller in chroma. Figure 6 exhibits two wedges of the color solid (sphere). Each one illustrates a pure hue located at it's full chroma position on its natural

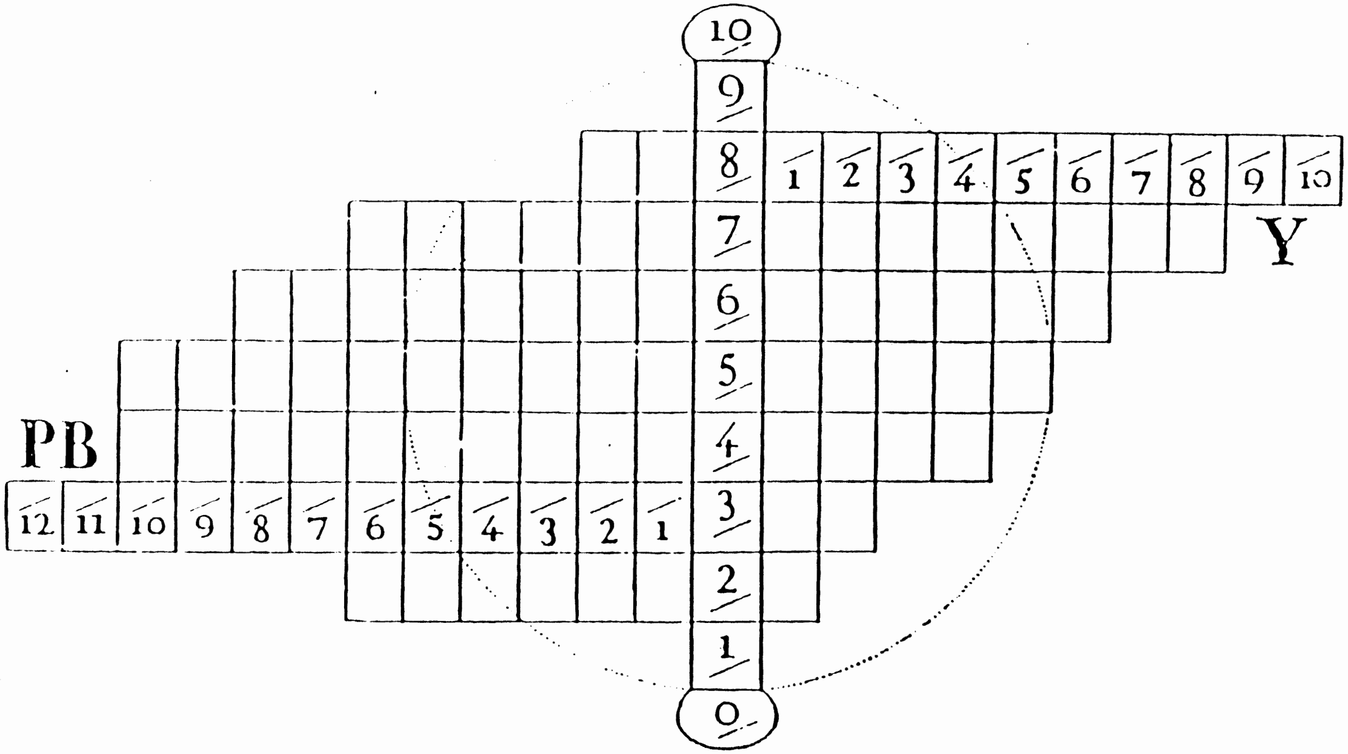


Figure 6. Munsell color palette of two hues illustrating hue, value, and chroma.

value position. Note that the two pure hues are located not only at different value levels but are also different distances away from the central axis (Munsell, 1929).

Each change in chroma is also indicated numerically in the notation of each hue. The notation system varies slightly since all pure hues do not exist the same distance from the central axis due to their natural difference in chroma. The central axis, consisting of greyed or totally neutralized hues are given the numerical notation of 0. As brightness increases the numbers rise until pure hue/pure intensity is reached at the outermost portion of the sphere.

Color and Perception

The vast number of studies on color and perception have dealt with an infant's ability to perceive color. A study by Teller (1981) demonstrated that there are clear age trends in the ability to discriminate selected hues from a background. At one month most of the infants failed to discriminate red, green or both stimuli from the yellow background. However, at 2 months of age more than half succeeded and at 3 months of age only one data set showed a failure by one infant to discriminate (Teller, 1981).

Frome, Piantanida, and Kelly in 1982 found that classically diagnosed dichromats did have three cone types rather than two. One set of cones (anomalous) which were previously thought to be absent, were in reality less sensitive to light. Because of insensitivity of these cones it makes the dichromat's visual disorder (red-green dichromacy) second only to color blindness. Frome, Piantanida, and Kelly were able to isolate the "missing" cone and measure the amount of response it was able to produce (Fromme, et al., 1982).

Peeples and Teller also studied the ability of infants to discriminate between variances in white colored stimuli. Keeping the intensity of the stimuli constant during the testing period, Peeples and Teller judged that infants of at least 2 months are dichromatic. That is, they have the ability to discriminate any single pair of lights (such as white and red) based on wavelength composition. If an organism can make subtle discriminations about every wavelength they are said to be trichromatic. If an individual is trichromatic three functioning receptor mechanisms need to be operational (Peeples & Teller, 1975). Joseph Fagan found that infants are capable of hue discrimination by as early as 4 to 6 months and the greater the difference in a hue from it's background the more easily the hue discrimination (Fagan, 1974). Bornstein in 1976 states that infants encounter the visual world with a bias. An infant's perception and their memory for hue are organized prior to formal training or tuition. Infants, according to Bornstein, will recognize hue after relatively short exposures and can remember a hue for at least short periods of time. This reaffirms previous research that hue memories can be thought of as a learned behavior as opposed to being intuitive or in-born.

The difficulty that arises from infant hue discrimination is the control of the normal brightness variations that occur from hue to hue. The adult will perceive some particular hues as brighter even though the physical intensity is equal. This factor has been accounted for in research by equating different hues for brightness on the basis of adult judgments (Fagan, 1974).

The percentage of individuals suffering from a color defect approximates eight percent, mostly male, of the western world (Voke, 1981). The frequency of visually color-defective people can vary within even a country (Vernon & Straker, 1943). Tests for color defects in non-Western cultures indicate smaller frequencies than on Western samples (Davidoff, 1975). According to Faber Birren (1978) less than one-half of one percent of women suffer from a color deficiency disorder. The usual definition of a visual color disorder is color blindness. Unfortunately this term is a misnomer. This condition is very rare and few men suffer from the inability to see any color. More likely is the inability of 1 in 50 men to see a certain range of hues.

The more common minor defects are confusion of some hues; reds, browns, oranges, yellows and greens. Most color defects are inherited but can also be acquired by disease or can be side effects of drugs or poison. Pickford in 1949 also found evidence of hysterical color-blindness according to personality changes (Davidoff, 1975).

Color vision defects are classified into five categories, every defect having specific problems associated with each individual category. The first, protanopia, is the inability to distinguish blue, green or red with grey and specifically confusing brown with red or black. Deuteranopias confuse reddish purple with grey and will confuse green with brown or red and green-blue with purple. The third classification is protanomalous and refers to individuals who confuse pale red with grey and yellow with orange. The fourth category consists of deuteranomalous or anomalous trichomats. To these individuals pale purple will appear grey and they will confuse green with yellow. The rarest defective vision type is the tritan where a confusion of violet or yellow with grey and green with blue exists (Voke, 1981).

As the eye ages there is an increased absorption of short wavelengths in the lens. This theoretical absorption of the eye is based on the absorption of water. The cornea cuts off infra-red radiation at 2 nanometers (wavelengths) and nothing reaches the retina beyond 1.4 nanometers. The water of the eye, in a simplistic viewpoint, filters the rays that can cause permanent damage to the retina (Wright, 1967). According to Voke (1981) the ordinary aging process also leads to defects in blue perception as a result of the clouding of the lens.

The interaction of the light and the surfaces that it illuminates can best be described by Wright in his 1964 publication The Measurement of Colour. "The colouring power of a dye or pigment is nothing more and nothing less than the power to reduce the energy in certain parts of the spectrum relative to the remainder" (Wright 1964, p.38). "The appearance of a pigment will, however, differ from the spectral radiation most akin to it, owing to the admixture of radiations from many other parts of the spectrum" (Wright, 1964, p.42). The ability of a surface to reflect certain wavelengths in cooperation with the eye's ability to translate those wavelengths constitutes color perception. It must be understood that the process of adaption is a "...continually recurring experience whenever we go from a higher to a lower illumination, and vice versa" (Wright, 1964, p.47).

Light needs to regarded generally as a physical phenomena that results from various amounts of energy being transmitted from a source at a given speed at various frequencies. The visible spectrum, the energy that the human can see, is a very small portion of the total energy emitted in the atmosphere. According to Hering the sensation of black in the visible spectrum is "only a lesser degree of white" and that black is a sensation and not a minimal light energy (Hering, 1964, p.229).

Color Training

R. W. Pickford (1973) reports in the British Journal of Aesthetics on color defective art students and the resultant effects on their work. The author focused the research on a case study of a 33 year old painter by the name of John Nicol. At an early age the artist was diagnosed as being color blind when he painted red for grass and green for a red mailbox. Later in the Army Nicol was tested with the Eldridge-Green Colour Perception Lantern Test and the Ishihara Pseudoisochromatic Plates. Obviously failing these tests the artist was still unable to learn any more information concerning his defects.

Leaving the Army and having previously demonstrated an aptitude for drawing, Nicol made his living as an artist. Having no formal training in art, Nicol worked primarily in black and white until the need to expand to color. For three years Nicol concentrated on working with color with the help of his wife and relying on the names on the paint tubes. The artist was able to paint quite successfully but in limited palettes. Nicol's color disability was the inability to distinguish between red and greens and to compensate for this the artist never used red and green in the same painting.

During the study the artist was further tested with an expanded version of the Ishihara test and the Pickford-Nicolson Anomaloscope. The subsequent tests indicated that red color sensation was diminished and that the perception of green as yellow existed. Pickford derived from interviews and tests that an individual could be taught to overcome the inability to distinguish colors.

Trevor-Roper suggests that many artists chose colors for their paintings based on some color defect in their vision. Certain artists as they age, have adjusted their palettes to compensate for the 'yellowing' of the lens (Trevor-Roper, 1970). The development of not only a color language but the ability to train and retain color information has been studied by Park and James. Concerned with the processing of spatial and color information by children, results show that "color memory is poorly retained unless subjects tries to learn it" (Park and James, 1983, p.66).

Summary

Major criticism of the research conducted in color can be expressed on several grounds. First, that the colors that are used for the stimulus colors have not been clearly specified. Second, hue has been the only variable of interest and value and saturation have not been controlled. Third, a standard light source has not always been used. Last, few studies have used any type of screening process for color vision dysfunction (Gelineau, 1981). The above mentioned criticisms relate to the obvious gaps in the research conducted by color researchers.

The amount of research and writings on the physiology of the eye are quite extensive and except for a few discrepancies reflect the same information. Information on hue discrimination is limited to studies of infant's abilities to recognize color rather than the ability to highly discriminate.

The interaction of the eye, light, pigment or coloring, and abilities must be considered in any research. However, some conclusions can be drawn from each of the separate studies that are available.

First, the structure of the eye itself is restrictive in the amount of light reaching the retina. Second, pigment theory of color is based on the ability of any colored surface to reflect those wavelengths in the visible spectrum that will 'color' that surface; blue surfaces reflect blue wavelengths. Third, the ability of an individual to train the eye to compensate for physical disorders.

If a colored surface, such as an iris, is reflecting wavelengths in a particular section of the spectrum, and if the lens and cornea restrict refraction of the light entering the pupil, can the resultant light reaching the retina be altered significantly? Can training in color alter the ability of individuals to discriminate colors? This study is designed to approach these questions and to arrive at some conclusions.

CHAPTER III

METHODOLOGY

Introduction

Historically, academic thought has been that the construction of a research design for a color study must be approached by one of the two paths that Acking and Kuller (1972) discuss, that is either color preference or the physiological relationship between color and light. Research has not approached the question of visual color perception based on human physical traits and the color education experiences of individuals. The purpose of this study was to examine differences in hue discrimination among individuals with different eye colors and levels of educational training related to color.

Research Design

According to Bobbit and Diana (1988) the qualitative research approach is inductive in character. "Induction involves the development of generalizations from specific observations" (Babbie, 1986, p. 46). In inductive logic the researcher is looking for patterns that summarize or represent the observations. The orientation of inductive or qualitative research is one of emerging or developing variables and the identification of existing or emerging questions that explain 'why'. The purpose of this type of research is to understand a situation or an event and is based upon interpretation of observed information and the constructs are generated from the researcher's knowledge base, perceptions, and insights gained via data collection/interpretative processes.

Qualitative research is generally descriptive, reflective, interpretative and ethnographic in nature and the uses entail expansion of knowledge, development of program direction, and to provide support for further programs. The strengths of this approach are the generation of themes, concepts, and insights. Data collection generally takes the form of observations, interviews, mapping, charting, and sociometric analysis. Typical research techniques employed in qualitative research include case studies, interviews, participant observation, and interpretative comments about observations. Qualitative research is limited however because of the restriction to "one time", "one place" applicability (Bobbit, 1990). The future implication of outcomes of qualitative/inductive research is "to understand what is or what might be" (Bobbit, 1990, p. 5).

The research design of this study was exploratory in nature and consisted of a factorial arrangement of treatments in a completely randomized design, (4x3x2). The purpose of the study was to investigate the relationships that might exist among the hue discrimination ability of individuals with different major courses of study, varying levels of color education, and different eye colors. Exploratory studies are conducted for three main purposes; (1) to better understand a research topic, (2) to test the feasibility of undertaking a more focused study, and (3) to develop methods to be used in additional studies. Exploratory studies are utilized in social science research and are "essential for breaking new ground and adding new insights into topics of research" (Babbie, 1986, p.73). This study served as an exploratory study to break ground in an area of color research not yet explored.

Variables for the exploratory study are illustrated in Figure 7 and are based on limited previous findings that suggest the need for further research in this area. According to this proposed research, a relationship exists among major course of study, color education, and eye color and the total score, tray scores, and range scores achieved by individuals on the Farnsworth-Munsell 100 Hue Discrimination Test.

Research Questions

Based upon an understanding of an existing color theory the research questions to be examined were as follows:

1. Are there significant differences in hue discrimination as measured by the Farnsworth-Munsell 100 Hue Discrimination Test among art, interior design,

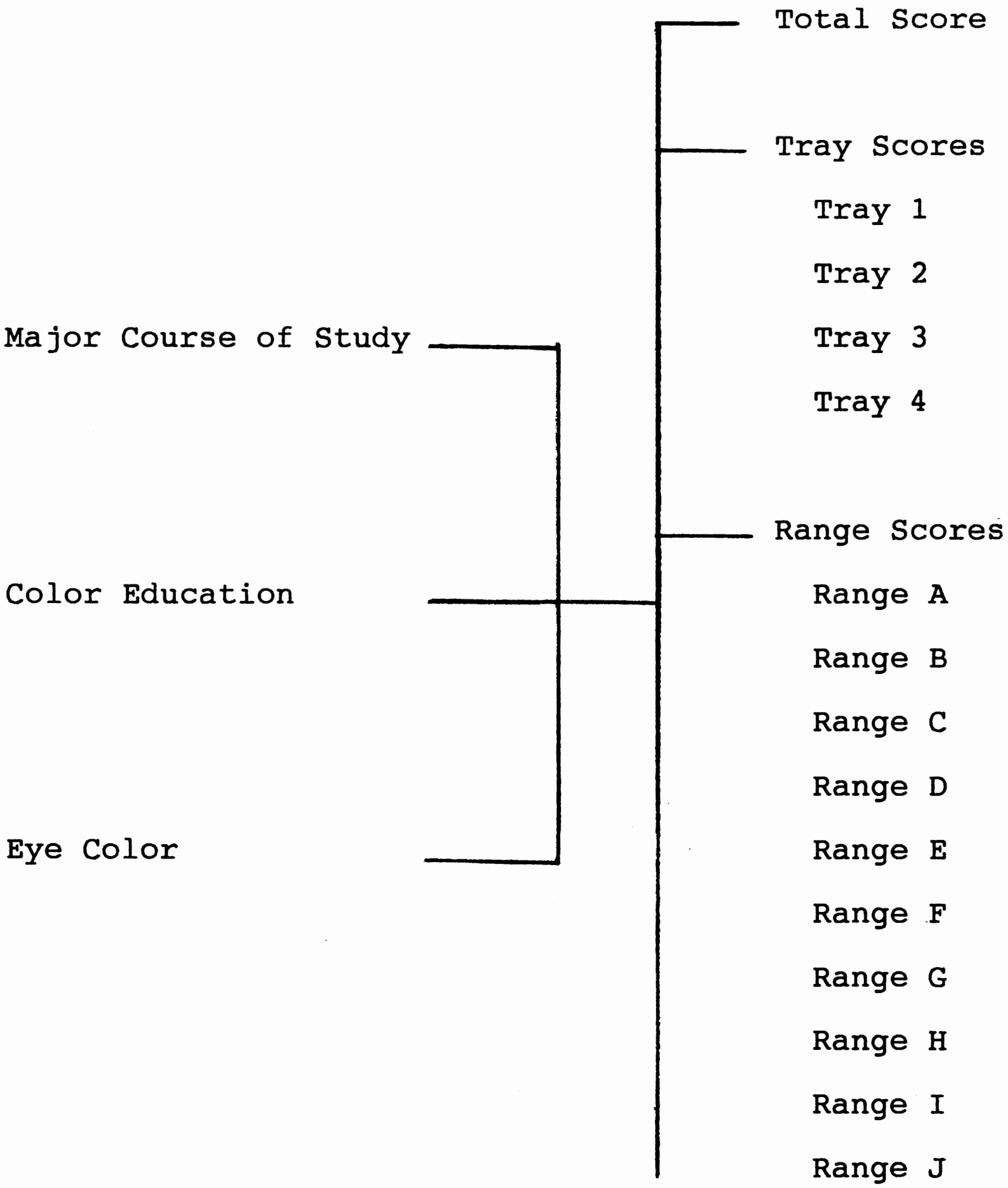


Figure 7. Variables to be Studied.

architecture, and landscape architecture students?

2. Are there significant differences in hue discrimination as measured by the Farnsworth-Munsell 100 Hue Discrimination Test between students with low or high levels of color education?

3. Are there significant differences in hue discrimination as measured by the Farnsworth-Munsell 100 Hue Discrimination Test among individuals with blue, brown, and green eyes?

4. Are there significant differences in hue discrimination as measured by the Farnsworth-Munsell 100 Hue Discrimination among art, interior design, landscape architecture, and architecture students with low or high levels of color education?

5. Are there significant differences in hue discrimination as measured by the Farnsworth-Munsell 100 Hue discrimination Test among art, interior design, landscape architecture, and architecture students with blue, brown or green eyes?

6. Are there significant differences in hue discrimination as measured by the Farnsworth-Munsell 100 Hue Discrimination Test among individuals with blue, brown, or

green eyes with low or high levels of color education?

7. Are there significant differences in hue discrimination among art, architecture, interior design, and landscape majors with blue, green, or brown eyes that have either high or low levels of color education?

Sample

Selection of participants included students enrolled at Oklahoma State University who were majoring in art, architecture, interior design, and landscape architecture. Upper division courses, 3000 or 4000 level, were identified in the four majors that were offered during the same time of the day. Arrangements were made with instructors of the classes for data collection to be made during scheduled class time. Testing was scheduled between due dates of class assignments to ensure lack of interference of class work.

Upper division courses were used to assure a higher number of majors in the courses chosen. Two courses, one 3000 level and one 4000 level, were chosen from each area of study from the semester offerings to allow for a wider range in color courses taken in the subject's program of study.

Instrumentation

The constructs of the research design were two fold; (1) a color test that could evaluate a subject's ability to discriminate hue and (2) a questionnaire to evaluate educational background and eye color. Two general types of tests for color ability exist. These include tests for color vision and tests for color-field. A third type of color ability test that exists is the test that evaluates color discrimination (Burnham, Hanes & Hartleson, 1963).

Color discrimination tests are subdivided into two subclasses; perceptual and memory. The Farnsworth-Munsell 100 Hue Discrimination test represents the former of those two subclasses. Selection of The Farnsworth-Munsell 100 Hue Test was based on the use of this test in previous research.

Examination

The Farnsworth-Munsell 100-Hue Test is designed as a test for color discrimination. It is designed to gather data that can be used "to separate persons with normal color vision into classes of superior, average and low color discrimination, and ..., to measure the zones of color confusion of color defective persons" (Farnsworth, 1957, p.2). "There are two purposes for which the 100-Hue Test was not intended: (a) it was not intended to distinguish fine degrees of differences between persons of superior aptitude, and (b) it was not intended to dichotomize color deficiency into 'pass and fail' classes" (Farnsworth, 1957, p.2). According to Wright in his review of testing materials, by using The Farnsworth-Munsell 100 Hue Test a defective observer's score on the test will reflect the type and magnitude of the defect (Wright, 1964). Some special purposes that the Farnsworth-Munsell has been used for include detection of poor color vision in salesmen, selection of applicants for vocational training, measurement effects of medical treatments, and as an independent control on validity of other color vision tests.

The materials of the test include four wooden cases containing a total of ninety-three plastic caps. Each tray contains two fixed caps which are used as pilot caps. The two hues on these caps are repeated within the unattached caps which thereby reduces the total number of hues on the color caps to eighty-five, (see Figures 8 and 9).

Each cap is numbered on the reverse side which in turn corresponds to the numbering on the scoring sheets. Figure 10 is an example of the scoring sheet accompanying the test.

Each cap has a color surface made of a matte-painted paper set into a black plastic cap. Matte surfaces are used in order to elicit the same spectral characteristics when viewed from any angle. The hues of the caps have been prepared to be a constant value and intensity throughout the four trays.

The Farnsworth-Munsell was administered under standardized daylight illumination. Natural daylight was used for the testing procedure and according to administration regulations this illumination was from a northern sky. Sky conditions were lightly to moderately overcast and approximated 6500 degrees Kelvin. To control

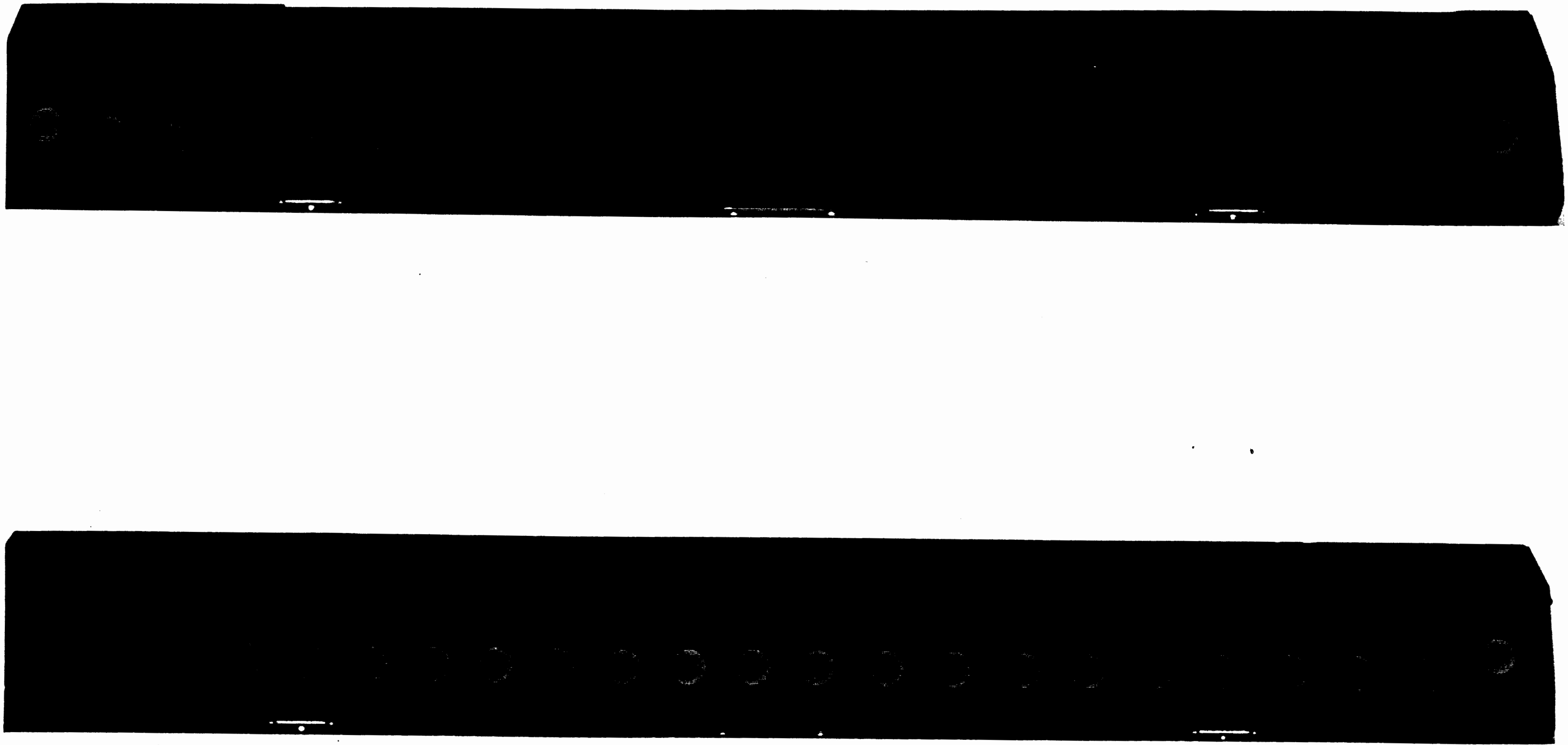


Figure 8. Tray 1 and Tray 2 of Farnsworth-Munsell
100 Hue Discrimination for Test

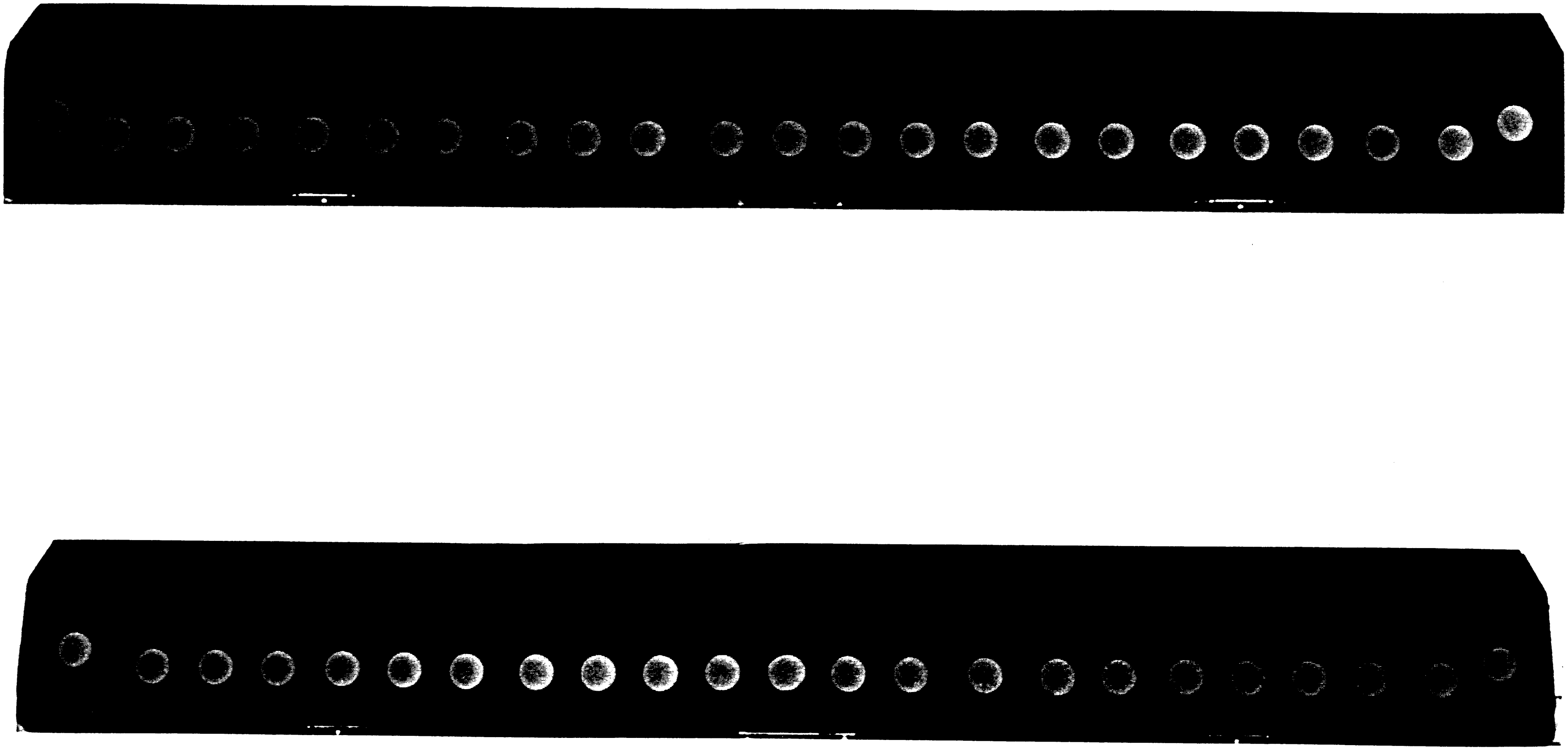
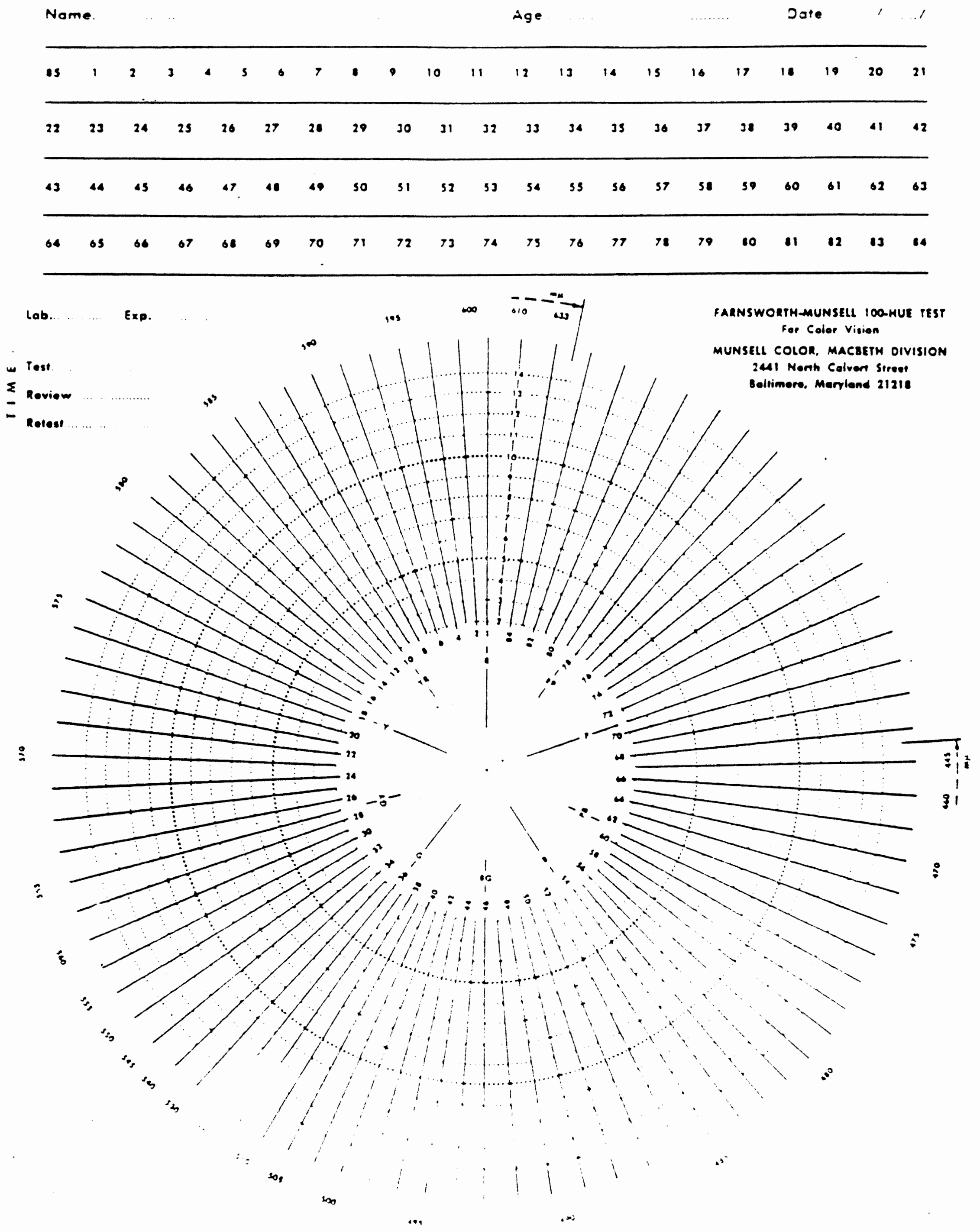


Figure 9. Tray 3 and Tray 4 of Farnsworth-Munsell 100 Hue Discrimination for Test



Name   Age   Date   /   /

85	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	31	32	33	34	35	36	37	38	39	40	41	42
43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84

Lab.   Exp.

TIME
Test
Review
Retest

FARNSWORTH-MUNSELL 100-HUE TEST
For Color Vision
MUNSELL COLOR, MACBETH DIVISION
2441 North Calvert Street
Baltimore, Maryland 21218

Figure 10. Score Sheet From Farnsworth-Munsell Test

for lighting variations, a light meter was used to determine proper specified administration light conditions. In addition all artificial illumination was eliminated from the testing area. Testing of the subjects, which occurred during scheduled class times, was limited to the hours between eleven-thirty and one-thirty. This also allowed for consistent daylight conditions.

During the examination period the administrator was seated directly opposite the participant. The lighting for the examination was from an angle of illumination of about 90 degrees and the viewing angle of the trays was about 60 degrees. Letting the trays set within the participant's cone of vision (60 degrees) allowed for better visual acuity.

Questionnaire

Each subject was asked to complete a demographic questionnaire (Appendix B) to obtain information concerning educational status, major, and courses taken. Selected questions to be utilized for this study are questions 15 and 24. Additional information was gathered concerning physical aspects of the subject and color educational background with the questionnaire that will be used for further studies.

Question #15 on the questionnaire asked for the subject's eye color according to their driver's license. This method was chosen for determining eye color based on a valid and legal documentation process. Information concerned with both previous attendance or current enrollment in courses having some aspect of color content in the subject matter was obtained with question #24 of the demographic questionnaire. Courses identified were those that made use of theoretical information, manipulation of light, manipulation of pigments of all kinds, and manipulation of all types of materials. These included such diverse courses as theatrical lighting, oil painting, and weaving. Courses also included those beyond the required of the four majors for the completion of their degree programs. Typical courses of this nature include those such as CTM 3002 Professional Image and Dress, TH 4813 Stage Costume Design, and HORT 2652 Basic Floral Design. Courses (Appendix A), as the ones mentioned above, were included to account for the possibility of students taking coursework of outside interest or those changing majors during their higher education.

Because this study was only concerned with subjects that were majoring in four aesthetic based courses of study it was assumed that there had been color training in their education at some time. Levels of color education were determined by number of credit hours of completed courses by participants during their education at Oklahoma State University.

The two levels were signified by either a low or high label. Low level background constituted any subject who had completed 0 through 18 credit hours of color content coursework. High level constituted any subject who had completed 19 or more credit hours of color content coursework.

Procedure

Administration of the test was repeated in the same manner for each subject and entailed the following testing procedure. One case was opened and placed before the subject on a surface that had been covered with a white cloth. The tray or panel had previously been arranged so that the loose caps were in random order in the upper lid. The tray with the two fixed caps was adjusted so that it was closest to the subject.

The subject was then instructed as per the instructions accompanying the test to do the following:

> The object of the test is to arrange the caps in order according to color. Please transfer them from this panel (examiner points to upper panel) and place them so they form a regular color series between these two caps (indicate both fixed caps). It should take you about two minutes per panel. However accuracy is more important than speed - so you will be told when the two minutes are up but the panel will not be taken away from you. Arrange them as best you can, but don't dawdle. Do you understand? Begin. (Farnsworth, 1957, p.3)

If the subject did not show comprehension the examiner said,

> Take the button which looks most like that (indicate the pilot button) and place it there..and the button most like that (indicate the last one) and place it there, and so on. (Farnsworth, 1957, p.3)

A subject was allowed as much time as was necessary to arrange the caps. It was most important that the arrangement be to their satisfaction. When the subject had completed a tray the process was repeated with the remaining three trays.

The Farnsworth-Munsell test was scored in three separate procedures. Each subject was scored for 1) an overall total test score, 2) on each of the four trays, and 3) on the ten ranges of hues of the test. Scores were calculated from a placement-displacement criteria. If a disk had a correct placement a zero value was assigned. Displacement of a disk resulted in an absolute value of the difference between correct and incorrect placement value. For example, if disk 3 was placed in the disk 1 position, then a value of 2 was added to the score. Low scores on the test or any portion of the test were preferred.

Data Analysis

To measure the relationships that exist among hue discrimination abilities of individuals with different eye colors and levels of color education, multivariate analysis of variance (MANOVA) was utilized for data analysis of the study variables. Prior to final analysis of the sample, preliminary data analysis was dictated by sample and data collection constraints.

Data were first collected at Oklahoma State University in Spring semester of 1983. Sample size of this data set was found to be small for analysis, therefore additional data were collected in the Fall semester of 1989. Because data collection occurred at a six year interval and the unusual gender distribution patterns of the samples, analysis of the two samples was conducted to determine similarities and differences between the samples.

First, analysis was conducted to evaluate whether gender distribution was affecting the study. Architecture and interior design students were of primary interest since the architecture portion of the sample was primarily male and the interior design portion was primarily female. In Sample I, 49 percent of the total sample size was male and 51 percent was female. Of the 32 architecture students in the sample, 30 were male. Of the 41 interior design students in Sample I, 36 were female (see Table I). In Sample II, 30 of the 43 architecture students in the sample were male and 34 of the 40 interior design students in the sample were female. The total sample of 242 consisted of 123 males or 51 percent and 119 females or 49 percent. Of the 123 males, 60 were architecture majors or 48.8 percent of the male portion of the sample. Of the 119 females in the total sample 70 were interior design majors or 58.8 percent of the female portion of the sample. It was thought

TABLE I

FREQUENCY DISTRIBUTION OF COMBINED SAMPLE I AND II MAJOR AND GENDER

	Sample I			Sample II			Combined		
Major	Male	Female	Total	Male	Female	Total	Male	Female	Total
Architecture									
n	30	2	32	30	13	43	60	15	75
percent							24.8	6.2	31
Landscape Architecture									
n	10	6	16	23	5	28	33	11	44
percent							13.6	4.6	18.1
Art									
n	7	10	17	12	13	25	19	23	42
percent							7.9	9.5	17.4
Interior Design									
n	5	36	41	6	34	40	11	70	81
percent							4.6	28.9	33.5
Total N							123	119	242
Total percent							51	49	100

that this high of percentage of the gender distribution difference in architecture and interior design could skew the studies. Analysis of variance was used to analyze Sample I, Sample II and the combined samples. On both individual samples and the merged samples, gender was not significant among majors (F (4, 237) = 2.12. p = .1469).

Second, analysis of the two samples was conducted to evaluate if any significant differences existed between the two because of the time difference. In order to evaluate the two samples for differences and similarities a dummy variable was first created called Study. Multiple regression analysis was then performed on the data and resulted in a multiple $R^2 = .31$. An F test was then conducted on the study variables and all study variable interactions. No significant differences were found between the two samples, F (7, 222) = 1.067, p =.3857 > .05. Since no significant differences existed between the samples they were then merged to form one sample. After merger of the two samples, multivariate analysis of variance (MANOVA) was utilized for analysis of the data.

Summary

The research design process for color research has in the past been categorized into two general classifications, color preference, and the physiological relationship between color and light. This study proposed to fill a gap in the existing research between the physiological research and preference research by the use of both a human physiological trait and color education background. This study examined hue discrimination ability through the evaluation of eye color and color educational background.

Two instruments were used to gather the data for this study. A questionnaire was used to gain information concerning the subject's eye color and level of color educational background. In addition to the questionnaire the Farnsworth-Munsell 100 Hue Test was administered to examine the subject's color discrimination ability.

Chapter IV

THE RELATIONSHIP BETWEEN HUE DISCRIMINATION, DESIGN RELATED COURSES OF STUDY, AND COLOR EDUCATION

MANUSCRIPT FOR PUBLICATION

JOURNAL TITLE: HOME ECONOMICS RESEARCH JOURNAL

THE RELATIONSHIP BETWEEN HUE DISCRIMINATION, DESIGN RELATED COURSES OF STUDY, AND COLOR EDUCATION

ABSTRACT

The purpose of this exploratory study was to examine differences in hue discrimination among individuals majoring in architecture, landscape architecture, art, and interior design with different levels of color education. The Farnsworth-Munsell 100 Hue Discrimination test was utilized to distinguish differences in color discrimination.

Analysis of the test scores indicated a relationship in the ability to discriminate between hues and levels of color education. Specific areas of the color spectrum indicated a particular relationship with color education and the ability to discriminate hues. The hues of green-yellow through red-purple indicated significant differences with the two levels of color education.

Data suggested little relationship between academic major and hue discrimination with the exception of the green range. A significant interaction existed only between major and color education in the blue range of the spectrum.

INTRODUCTION

Historically, academic thought indicates that a research design for a color study must be approached by one of the two paths that Acking and Kuller (1972) discuss; either color preference or the physiological relationship between color and light. Research largely has ignored the question of visual color perception based on human physical traits and the color education experiences of individuals.

Color perception is an intricate and complex process. The perception of hue, what the human sees and defines as a color, is an individually based process. The actual color that will be seen by the eye depends on a series of factors, internal as well as external, which are linked together in a rather complex chain, some parts of which are more difficult to trace than others owing to the limitations of our knowledge (Southall, 1937). These theories and views on eye physiology and color perception developed in the last century are still recognized and generally accepted today (Haapasalo, 1982).

LITERATURE

Color perception, the ability to see color, is closely linked to the human's ability to discriminate between hues. Most information on hue discrimination reflects the studies of infant's abilities to recognize color rather than the ability to highly discriminate. A study conducted by Teller (1981) demonstrated that there are clear age trends in the ability to discriminate selected hues from a background. At one month most of the infants failed to discriminate red, green or both stimuli from the yellow background. However, at 2 months of age more than half succeeded and at 3 months of age only one data set showed a failure by one infant to discriminate.

Peeples and Teller also studied the ability of infants to discriminate between variances in white colored stimuli. Keeping the intensity of the stimuli constant during the testing period, Peeples and Teller judged that infants of at least 2 months are dichromatic. That is, they have the ability to discriminate any single pair of lights (such as white and red) based on wavelength composition. If an organism can make subtle discriminations about every wavelength they are said to be trichromatic. If an individual is trichromatic three functioning receptor mechanisms need to be operational (Peeples & Teller, 1975).

Frome, Piantanida, and Kelly (1982) found that classically diagnosed dichromat did have three cone types rather than two. One set of cones (anomalous) which were previously thought to be absent, were in reality less sensitive to light. Because of insensitivity of these cones it makes the dichromat's visual disorder (red-green dichromacy) second only to color blindness. Frome, Piantanida, and Kelly were able to isolate the "missing" cone and measure the amount of response it was able to produce (Fromme, et al, 1982).

The percentage of individuals suffering from a color defect approximates eight percent, mostly male, of the western world (Voke, 1981). According to Birren (1978), less than one-half of one percent of women suffer from a color deficiency disorder (Birren, 1978). The usual definition of a visual color disorder is color blindness. Unfortunately this term is a misnomer. This condition is very rare and few men suffer from the inability to see any color. More likely, it is the inability of 1 in 50 men to see a certain range of hues.

The more common minor color deficiencies are the confusion of some hues; reds, browns, oranges, yellows and greens. Most color deficiencies are inherited but can also be acquired by disease or can be side effects of drugs or poison.

As the eye ages there is an increased absorption of short wavelengths in the lens. This theoretical absorption of the eye is based on the absorption of water. The cornea cuts off infra-red radiation at 2 nanometers (wavelengths) and nothing reaches the retina beyond 1.4 nanometers. The water of the eye, in a simplistic viewpoint, filters the rays that can cause permanent damage to the retina (Wright, 1967, p.87). According to Voke (1981) the ordinary aging process also leads to defects in blue perception as a result of the clouding of the lens.

The interaction of the light and the surfaces that it illuminates can best be described by Wright in his 1964 publication <u>The Measurement of Colour.</u> "The colouring power of a dye or pigment is nothing more and nothing less than the power to reduce the energy in certain parts of the spectrum relative to the remainder" (Wright 1964, p.38). "The appearance of a pigment will, however, differ from the spectral radiation most akin to it, owing to the admixture of radiations from many other parts of the spectrum" (Wright, 1964, p.42). The ability of a surface to reflect certain wavelengths in cooperation with the eye's ability to translate those wavelengths constitutes color perception.

The development of not only a color language but the ability to train and retain color information has been studied by Park and James. Concerned with the processing of spatial and color information by children, results of their 1983 study indicate that "color memory is poorly retained unless subjects <u>try</u> to learn it" (Park & James, 1983).

R. W. Pickford (1973) reports in the British Journal of <u>Aesthetics</u> on color defective art students and the resultant effects on their work. The author focused the research on a case study of a 33 year old painter by the name of John Nicol. At an early age the artist was diagnosed as being color blind when he mistakenly painted red for grass and green for a red mailbox. Later, Nicol was tested with the Eldridge-Green Colour Perception Lantern Test and the Ishihara Pseudoisochromatic Plates. Obviously failing these tests, the artist was still unable to learn any more information concerning his defects.

Demonstrating an aptitude for drawing, Nicol made his living as an artist. Having no formal training in art, Nicol worked primarily in black and white until the need to expand to color. For three years Nicol concentrated on working with color with the help of the his wife and relying on the names on paint tubes. The artist was able to paint quite successfully but in limited palettes; those that never utilized red and green in the same painting.

During the study the artist was further tested with an expanded version of the Ishihara test and the Pickford-Nicolson Anomaloscope. The subsequent tests indicated that red color sensation was diminished and that the perception of green as yellow existed. Pickford derived from interviews and tests that an individual could be taught to overcome the inability to distinguish colors.

Throughout a human life the learning process involves both regimented learning and learning through life experience. As a child, one is taught that an apple is red or the sky is blue by either a parent or other care giver by simply saying that the apple is red or the sky is blue. Later in the formalized educational setting of the classroom a youngster learns ideas through reading and other individual's shared experiences. More complex ideas can be incorporated into the store of knowledge later in their lives by continued readings of more complex theories or by utilizing colored materials and media in day to day activities.

Early color theory education involves teaching a youngster that red and yellow paints mixed together results in orange. This simple statement is usually followed by fingerpainting or some other hands-on manipulation. Required art classes end early in a child's education, usually by the end of junior high or middle school. The materials utilized in this education process are generally limited to colored paper and paint. Unfortunately, lack of time in the classroom and use of limited materials could limit the color learning process for many individuals. Materials and media such as paint, light, paper, fibers/fabrics, and building and plant materials, are some of the typical materials used by individuals associated with the creation of environments. If a student is exposed to color training by either reading about theories or by the manipulation of environmental materials is there a difference in their ability to recognize change in hue, value or intensity of color? The purpose of this study was to examine differences in hue discrimination among individuals with different college majors related to aesthetics and levels of color education.

The following objectives were used to guide the study.

1. To assess the relationships among hue discrimination and individuals majoring in the aesthetic related areas of art, architecture, interior design and landscape architecture.

2. To assess the relationship between hue

discrimination and individuals with high and low levels of color education.

METHODOLOGY

Research Design

The research design of this study was exploratory in nature and consisted of a factorial arrangement of treatments in a completely randomized design, (4x2). The purpose of this study was to investigate the relationships that might exist among the hue discrimination ability of individuals with different major courses of study and varying levels of color education. Exploratory studies are conducted for three main purposes; (1) to better understand a research topic, (2) to test the feasibility of undertaking a more focused study, and (3) to develop methods to be used in additional studies. Exploratory studies are utilized in social science research and are essential for "breaking new ground and adding new insights into topics of research" (Babbie, 1986, p.73). This study served as an exploratory study to break ground in an area of color research with little exploration.

Sample

Selection of subjects included students enrolled at a midwestern university who were majoring in the aesthetic related areas of art, architecture, interior design and landscape architecture. Students in the four majors were selected for the sample from upper division courses that were offered during the same time of the day. Upper division courses were used to assure a higher number of majors in the courses chosen. Two courses, one 3000 level and one 4000 level, were chosen from each area of study from the semester offerings to allow for a wider range in color courses taken in the subject's program of study.

The final sample consisted of 242 subjects; 123 males (51%) and 119 females (49%). Distribution and percentages of the gender and majors in the sample are represented in Table II.

Insert Table II Here

Instrumentation

The Farnsworth-Munsell 100-Hue Test is designed as a simple test for color discrimination. It is designed to gather data that can be used "to separate persons with normal color vision into classes of superior, average and low color discrimination, and ..., to measure the zones of color confusion of color defective persons" (Farnsworth, 1957, p.2).

The materials of the test include four wooden cases containing a total of ninety-three plastic caps. Each tray contains two fixed caps which are used as pilot caps. The two hues on these caps are repeated within the unattached caps which thereby reduces the total number of hues on the color caps to eighty-five.

Range of hues were identified from the ten principal hues of the Munsell system. Each range consisted of the disks associated with a principal Munsell hue. For example, Range C consisted of all the disks associated with Munsell yellow. The disks of the test assigned to the yellow range or Range C would be numbers 14 through 22. Range A represents red, B yellow-red, C yellow, D green-yellow, E green, F blue-green, G blue, H purple-blue, I purple, and J red-purple.

The Farnsworth-Munsell 100 Hue Discrimination Test was administered under standardized daylight illumination. Natural daylight was used for the testing procedure according to administration regulations under illumination from a northern sky. Sky conditions were lightly to moderately overcast and approximated 6500 degrees Kelvin. To control for lighting variations, a light meter was used to determine proper light conditions. In addition all artificial illumination was eliminated from the testing area. Testing of the participants, which occurred during scheduled class times, was limited to the hours between eleven-thirty and one thirty. This allowed for consistent daylight conditions.

During the examination period the administrator was seated directly opposite the participant. The lighting for the examination was from an angle of illumination of about

90 degrees and the viewing angle of the trays was about 60 degrees. Letting the trays set within the participant's cone of vision (60 degrees) allowed for better visual acuity. In addition to the hue instrument each participant was asked to complete a demographic questionnaire to obtain information concerning educational status, major, and coursework. Information concerned with both previous or current enrollment in courses identified as having some aspect of color education in the subject matter was obtained. These courses included those that had instruction in theoretical information, manipulation of light, manipulation of pigments of all kinds, and manipulation of all types of materials. Included were such diverse courses as theatrical lighting, oil painting, plant materials, and weaving. Additional courses listed in the questionnaire included those beyond the requirements of the four majors for the completion of their degree programs.

Because this study was concerned only with students who were majoring in four aesthetic based courses of study it is assumed that there had been color training in their education at some time. Levels of color education were determined by number of credit hours of completed courses by participants during their education. The two levels were signified by either a low or high label. Low level background constituted any participant who had completed 18 or less credit hours of color courses. High level constituted any participant who had completed 19 or more credit hours of color coursework.

Procedure

Administration of the test was repeated in the same manner for each subject and entailed the following testing procedure. Case 1 was opened and placed before the subject on a surface that had been covered with a white cloth. The tray or panel had previously been arranged so that the loose caps were in random order in the upper lid. The tray with the two fixed caps was adjusted so that it was nearest to the subject. The subject was then instructed as per the instructions accompanying the test. A subject was allowed as much time as was necessary to arrange the caps. It was most important that the arrangement be to their satisfaction. When the subject had completed a tray the process was repeated with the remaining three trays.

The Farnsworth-Munsell test was scored in three separate procedures. Each subject was scored for 1) an overall total test score, 2) on each of the four trays, and 3) on the ten ranges of hues of the test. Scores were calculated from a placement-displacement criteria. If a disk had a correct placement a zero value was assigned. Displacement of a disk resulted in an absolute value of the difference between correct and incorrect placement value. For example, if disk 3 was placed in the disk 1 position, then a value of 2 was added to the score. Low scores on the test or any portion of the test were preferred. Table III

Insert Table III Here

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illustrates mean scores of major and color education levels for total score and tray scores. Table IV also illustrates the mean scores of major by color education levels for range scores.

Insert Table IV Here

Data Analysis

To measure the relationships that exist among hue discrimination abilities of individuals with different levels of color education, multivariate analysis of variance (MANOVA) was utilized for data analysis of the study variables. Prior to final analysis of the sample, preliminary data analysis was dictated by the sample and data collection constraints.

Data were first collected at a midwestern university in Spring semester of 1983. The sample size of this data set was found to be small for analysis, therefore additional data were collected in the Fall semester of 1989. Because data collection occurred at a six year interval and there were unusual gender distribution patterns of the samples, analysis of the samples was conducted to determine similarities and differences between the samples.

First, analysis was conducted to evaluate whether gender distribution was affecting the study. Architecture and interior design students were of primary interest since the architecture portion of the sample was primarily male and the interior design portion was primarily female. In Sample I, 49 percent of the total sample size was male and 51 percent was female. Of the 32 architecture students in the sample, 30 were male. Of the 41 interior design students in Sample I, 36 were female. In Sample II, 30 of the 43 architecture students in the sample were male and 34 of the 40 interior design students in the sample were female. It was thought that this difference in gender distribution in architecture and interior design could skew the results of the study. Analysis of variance was used to analyze Sample I, Sample II and the combined samples. On both individual samples and the merged sample, gender was not significant among majors (F (4, 237) = 2.12, p. = .1469).

Second, analysis of the two samples was conducted to evaluate if any significant differences existed between the two. In order to evaluate the two samples for differences and similarities a dummy variable was first created called study. Multiple regression analysis was then performed and resulted in a multiple $R^2 = .31$. An F test was then conducted on the study variables and all study variable interactions. No significant differences were found between the two samples, F (7, 222) = 1.067, p = .3857. Since no significant differences existed between the samples they were merged to form one sample.

Results and Discussion

Multivariate analysis of variance (MANOVA) for a 4 X 2 factorial arrangement of treatments in a completely randomized design on the two independent variables (major and color education) and for all scoring procedures (total, trays and ranges) indicated some interesting findings. Wilk's Criterion, used as the hypothesis test procedure for no overall effect on tray scores, indicated a significance for color education with an $\underline{F}$ (4.231) = 5.85, $\underline{p}$ = .0002. Wilk's Criterion also indicated a significance for color education on total score, $\underline{F}$ (1,234) = 21.04. $\underline{p}$ = .0001. Range scores on color education tested with Wilks Criterion were also significant with an $\underline{F}$ (10,225) = 2.90, $\underline{p}$ = .002. Further results are described below.

Total Score

Table V illustrates the results of univariate analysis of variance performed on total score. A significant main effect for color education was found, $\underline{F}$ (1, 240) = 24.84, $\underline{p}$ = .0001. Neither major as a main effect nor the major by education interaction were significant for the total score.

Insert Table V Here

Tray Scores

Tray scores were calculated and analyses for all four trays was conducted. Tray 1 represents the red, yellow-red, and yellow portion of the Munsell color wheel; Tray 2, green-yellow, green and part of the blue green; Tray 3, part of blue green, blue an purple-blue; and Tray 4, part of purple-blue, purple and red. Results of the analysis are summarized in Table VI. There was no major by color education interactions (p >. 07) for any of the tray scores and major as a main effect was not significant (p >.18) for any of the four trays. Color education as a main effect was found significant (p <.002) in all of the four trays.

Trays 1, 2, 3, and 4 were significant at a critical value of the p <.05. The calculated F ratio for Tray 1 representing the warm colors of the spectrum, red, yellow-red and yellow, was F (7,234) = 18.60, p = .0001. Tray 2 was also significant with a calculated F (7,234) = 13.83, p = .0003 and included yellow-green, green and part of the blue-green portion of the test. Tray 3, which was also significant had a calculated F (7,234) = 9.89, p =.0019. This tray represented the blue-green, blue and part of purple-blue portions of the Farnsworth-Munsell Test. Tray 4 which included portions of the purple-blue, purple, and red-purple, was significant for color education with an F (7,234) = 16.93, p =.0001.

Major by education as a two-way interaction was not significant at the p = .05 level. Tray 3 however, approached significance at p = .07 with a F ratio of 2.34.

Insert Table VI Here

Range Scores

Table VII illustrates the results of univariate analysis of variance (ANOVA) for scores on each of the Ranges A through J. Major as a main effect was significant only at Range E. The calculated F (3,234) ratio was 3.42 and was significant at p =.0181.

Ranges D through J were significant for education as a main effect. The significance of the ranges varied from Range E (green) p =.0001 to Range G (blue) p =.0254. The other significant ranges included: Range D, green-yellow, (F (3, 234) = 9.99, p =.0018), Range F, blue-green, (F (3,234) = 7.98, p =.0051), Range H, purple-blue, (F (3, 234) = 7.48, p = .0067), Range I, purple, (F (3, 234) = 13.68, p = .003, Range J, red-purple, (F (3, 234) = 9.33, p =.0025). The remainder of the Ranges were not significant at the p <.05 .

The two-way interactions of major by education on the ranges were not significant at the alpha level of .05. Range G approached significance with a F ratio of 2.39 and a p-value of .0694.

Insert Table VII Here

SUMMARY AND CONCLUSIONS

The present results provide information of a possible relationship between hue discrimination and color education experiences. It must be noted that because course of study for career is self-selected the possibility exists that individuals, both male and female, who indicate highly decreased hue discrimination abilities choose non-color related careers and are not represented in this study. Because males and females in this study indicated no significant difference in their discrimination abilities the results neither support or reject the previous findings reported by Vernon and Straker (1943) or Birren (1978) that most color vision deficiencies are found in males. The results from this exploratory study would indicate that an individual's ability to discriminate among hues was similar in this sample.

Exposure to coursework containing color content, as defined and limited by this study, appears to relate to the hue discrimination ability of individuals. Although color content in each course was not controlled, there was a relationship between the number of credit hours in color related courses and the participant's ability to discriminate hues. Although limited because of the exploratory nature of this study and because color education was not manipulated, the results would indicate that not only does a relationship exist between hue discrimination and color education but that it is consistent with both

Pickford's (1973) case study that an individual can, over time 'train' themselves to successfully use a color even though there are physiological color deficiencies in their color vision, or that those who successfully use color take more credit hours in the specified courses than those who do not. Also this is consistent with Park and James (1983) findings of children's color processing by trying to learn or memorize a color and the ability to retain knowledge of a color .

A relationship was indicated between hue discrimination ability of specific areas of the color spectrum with color education. The green-yellow through red-purple portions of the test indicated the greatest change in the results of hue discrimination ability in relationship with color education. These results also support the findings of Pickford and Park and James that color education and experiences are related to an individual's ability to discriminate hues. It should be noted that the warm areas of the spectrum indicated no significant difference in hue discrimination ability in relationship to color education. Reasons for this lack of relationship could indicate that 1) warm colors are discernable at an early age and additional learning experiences do not change discrimination ability or 2) additional coursework is needed to indicate the change in the hue discrimination ability of those hues. Additional testing plus color education control of this specific area of the spectrum is needed to draw conclusions about the relationship. Because there is little existing research in the area of hue discrimination ability, findings of relationships of specific portions of the spectrum and discrimination would contribute to a better understanding of the process.

Data suggested that major had little relationship with hue discrimination with the exception of the green portion of the spectrum. This could reflect the fact that landscape architects utilize the green palette for the majority of their designs thereby focusing on a certain area of the color spectrum more intensely. This may indicate that individuals interested and concentrating on a specific palette have a tendency to change their hue discrimination ability through the manipulation or study of those hues. Further research concentrating on students majoring in design related areas of study and their color education, such as the most frequently used colors, specific areas of the spectrum used, how often color is used, needs to be conducted to draw any conclusions.

In summary, the present findings indicate a relationship between hue discrimination ability and color education experiences. Research should be conducted which further explores the interface between hue discrimination and course of study. In addition it is suggested that further research be conducted to study the relationship between hue discrimination and the warm colors of the spectrum to determine if additional education increases discrimination.

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TABLE II

FREQUENCY DISTRIBUTION OF SAMPLE BY MAJOR, GENDER AND COLOR EDUCATION

	MALE		FEMALE		TOTAL	
	n	%	n	%	n	%
MAJOR						
Architecture	60	24.8	15	6.2	75	31
Landscape Architecture	33	13.6	11	4.6	44	18.2
Art	19	7.9	23	9.5	42	17.4
Interior Design	11	4.6	70	28.9	81	33.5
TOTAL N	123		119		242	

TABLE III

MEANS OF TOTAL AND TRAY SCORES FOR MAJOR AND COLOR EDUCATION

MAJOR	n	TOTAL	TRAY 1	TRAY 2	TRAY 3	TRAY 4
ARCHITECTURE	75	47.37	21.72	8.15	10.99	6.52
LANDSCAPE ARCHITECTURE	44	55.34	24.75	8.64	12.86	9.09
ART	42	44.42	18.00	8.69	10.17	7.57
INTERIOR DESIGN	81	48.26	19.44	9.51	11.86	7.44
COLOR EDUCATION						
LOW	88	66.88	33.10	10.53	13.67	9.57
HIGH	154	38.17	13.87	7.79	10.23	6.29
MAJOR BY COLOR EDUCATION						
ARCHITECTURE						
LOW	35	66.37	34.00	9.83	14.06	8.49
HIGH	40	30.75	10.98	6.68	8.30	4.80
LANDSCAPE ARCHITECTURE						
LOW	21	77.05	39.19	9.71	16.14	12.00
HIGH	23	35.52	11.57	7.65	9.87	6.43
ART						
LOW	16	48.06	20.69	10.69	8.69	8.00
HIGH	26	42.19	16.35	7.46	11.08	7.31
INTERIOR DESIGN						
LOW	16	73.44	35.56	13.00	14.56	10.31
HIGH	65	42.06	15.48	8.65	11.20	6.74

TABLE IV

MEAN SCORES FOR RANGES OF MAJOR BY COLOR EDUCATION

MAJOR & COLOR EDUCATION	n	A	B	C	D	E	F	G	H	I	J
ARCHITECTURE											
LOW	35	2.80	3.49	4.31	4.49	7.89	6.11	5.57	3.66	2.97	29.89
HIGH	40	2.20	1.45	2.70	3.23	5.15	3.43	3.10	3.13	1.48	7.85
LANDSCAPE ARCHITECTURE											
LOW	21	3.57	2.62	3.57	5.05	9.00	5.71	6.29	5.71	4.10	36.33
HIGH	23	2.17	1.48	2.69	3.74	7.00	3.74	3.52	2.17	1.83	11.30
ART											
LOW	16	2.56	1.56	2.94	4.88	8.06	3.81	2.31	3.94	2.88	18.94
HIGH	26	2.69	2.50	3.42	3.81	5.73	4.62	4.42	3.04	3.38	12.58
INTERIOR DESIGN											
LOW	16	2.38	1.75	2.94	7.19	10.25	5.81	5.19	4.38	3.88	34.88
HIGH	65	1.54	1.38	2.65	4.26	7.92	4.66	3.43	3.14	2.25	14.26

TABLE V

ANOVA OF MAJOR AND COLOR EDUCATION FOR TOTAL SCORE

SOURCE	df	F	p-value
MAJOR	3	0.49	0.6865
COLOR EDUCATION	1	24.84 *	0.0001 *
MAJOR & COLOR EDUCATION	3	1.36	0.2562

* INDICATES SIGNIFICANCE OF $p \leq .0001$

TABLE VI

ANOVA OF MAJOR AND COLOR EDUCATION FOR EACH TRAY SCORE

		TRAY 1		TRAY 2		TRAY 3		TRAY 4	
SOURCE	df	F	p-value	F	p-value	F	p-value	F	p-value
MAJOR	3	0.37	.7726	0.62	.6006	0.84	.4721	0.63	.1835
COLOR EDUCATION	1	18.60 *	.0001	13.83 *	.0003	9.89 *	.0019	16.93 *	.0001
MAJOR*COLOR EDUCATION	3	0.98	.4016	0.26	.8516	2.34	.0737	1.11	.3445

* INDICATES SIGNIFICANCE AT $p \leq .0001$

TABLE VII

ANOVA OF MAJOR AND COLOR EDUCATION FOR EACH RANGE SCORE

		RED		YELLOW-RED		YELLOW		GREEN-YELLOW		GREEN	
SOURCE	df	F	p	F	p	F	p	F	p	F	p
MAJOR	3	1.81	.1467	0.83	.4763	0.58	.6288	0.98	.4021	3.42	.0181
COLOR EDUCATION	1	2.74	.0995	2.75	.0983	2.17	.1421	9.99 *	.0018	16.49 *	.0001
MAJOR BY COLOR EDUCATION	3	0.46	.7079	1.41	.2407	0.81	.4900	0.67	.5721	0.07	.9749

		BLUE-GREEN		BLUE		PURPLE-BLUE		PURPLE		RED-PURPLE	
SOURCE	df	F	p	F	p	F	p	F	p	F	p
MAJOR	3	.21	.8901	0.64	.5916	0.20	.8934	1.65	.1796	0.47	.7029
COLOR EDUCATION	1	7.98	.0051	*5.06 *	.0254	7.48 *	.0067	13.68 *	.0003	18.26 *	.0001
MAJOR BY COLOR EDUCATION	3	1.87	.1360	2.39	.0694	1.62	.1853	2.27	.0812	0.68	.5673

* INDICATES SIGNIFICANCE AT $p \geq .05$

CHAPTER V

HUE DISCRIMINATION AS RELATED TO EYE COLOR AND COLOR EDUCATION

MANUSCRIPT FOR PUBLICATION

JOURNAL TITLE: JOURNAL OF INTERIOR DESIGN
EDUCATION AND RESEARCH

HUE DISCRIMINATION AS RELATED TO EYE COLOR AND COLOR EDUCATION

ABSTRACT

The purpose of this exploratory study was to examine the relationship among individuals majoring in architecture, landscape architecture, art, or interior design with different levels of color education and different eye colors and the ability to discriminate hues. The Farnsworth-Munsell 100 Hue Discrimination Test was utilized to measure differences in hue discrimination. Low scores on the test were preferred. Results indicated a relationship between color education and hue discrimination ability. Seven of the ten hues studied indicated a relationship with the two levels of color education. Red, yellow-red, and yellow, the warm colors of the spectrum, indicated no relationship between color content coursework and hue discrimination ability.

Of the three different eye colors studied in this research, the strongest relationship existed between students with green eyes and their ability to discriminate color. No significant patterns of major were indicated in this study. Of the interactions that were significant, landscape architecture students appeared to score with the

least discriminate ability of all the groups on Tray 4. Other majors indicated no significant differences among themselves for this tray. Art students with blue eyes and interior design students appear to have the most difficulty discriminating the purple hues. Means for these two groups were the highest for all groups.

INTRODUCTION

Color is a much studied but still highly undefined phenomena. The avenues of study and theory development include psychological, physiological, chemical, and the aesthetic aspects of color. The problem that arises from these many areas of study is that they are all so interconnected that a researcher can rarely study one aspect without relating it to another. Color perception has been defined as the ability of a surface to reflect certain wavelengths in cooperation with the eye's ability to translate those wavelengths. This results in not only a complex biological and psychological process but in many ways a lack of understanding of color perception.

In the fields of design all of these aspects of study are utilized to create more pleasing environments. To create these environments and utilize the many aspects of color, designers, whether interior or exterior must depend on knowledge gained through physical abilities, education, and working experience.

The investigation of color as an integral part of the environment has been limited. Acking and Kuller (1972) classify the study of color into two groups: (1) color preference and (2) the physiological effects of color and colored light. These authors divide an individual's total perception of surroundings into certain factors; (1) a feeling of comfort and security, (2) estimation of social status, (3) description of appearance of space and light,

(4) the intensity or complexity of their environment, and last (5) the unity of the environment. They, however, fail to address the question of physiology and the environment.

The need to address how environmental specialists, such as architects, interior designers, artists, and landscape architects, visualize and perceive the surroundings becomes a paramount and important task. Birren (1972) states that "creative people by nature resist advice and counsel. To question their 'feeling' for color is like criticizing their religious views." If the physical differences of each human can be measured and judged, then it is important that an understanding be reached of how design judgments are made by individuals with color defects or lowered discrimination ability.

LITERATURE

According to Evans (1974) the complete subject of color divides into the physical causes "that produce the relatively simple final stimulus and the complex physiological and psychological reactions to this stimulus that produce the perception of color" (Evans, 1974, p.11). An understanding of physical characteristics of the eye and their influence on perception can then prepare an individual for making hue discrimination decisions.

The structure of the iris constitutes the front outer layer of the spherical form and the anterior surface of the iris is in contact with the aqueous humor. The iris functions as the major determinant of the amount of light entering the eye (Padgham & Saunders, 1975). Irises, acting as variable apertures that open and close, monitor the intensity of light changes in the environment for the eye. Constructed of colored fibrous material, it surrounds the central aperture called the pupil. "The iris behaves as a diaphragm, modifying the amount of light entering the eye, whilst the ciliary body contains muscle fibres which, on contraction, increase the refractive power of the lens (accommodation)" (Dawson, 1963, p.1). The pupil is subject to slight, but important control of the visual sense. However, it is more important as the one part of the entire visible sense affected by external factors. It also seems to be influenced by certain internal results of seeing (Luckiesh, 1944). Evans (1974) believes that the iris plays little part in the act of color perception except in the modification of lens aberrations. However, it must be remembered that the eye acts as a receptor and according to Palmer (MacAdam, 1980) all receptors and reception systems may differ and effect the total visual and color perception. Guild states that "The classification of receptors into different types is perfectly definite and depends solely on those physical properties of receptors which determine their relative sensitivity to radiation of different wavelengths" (MacAdam, p.199). If it is believed that physical properties affect the light reception and thereby the visual perception then the iris must play a role in that interpretation process.

The lens is the principal medium that affects the distribution of the incident visible light, that is, the light that falls directly on the eye. As the human ages the lens "yellows" and in turn increases the absorption in the blue region of the visible spectrum (Evans, 1974).

The lens, located behind the aqueous humour, is supported from behind with another transparent gelatinous material called the vitreous humour. The jelly-like substance is held together by a membrane called the hyaloid. The hyaloid also adheres the vitreous substance to the retina. The lens adjoins the rear surface of the iris (Wright, 1964).

The inside of the rear portion of the choroid is covered by the retina. Until the sixteenth century it was thought that the lens was the main component in producing an image and translating that image to the brain. However, in 1866 Schultz identified two types of receptors located in the retina of a variety of animal eyes that are now accepted as mediating the visual response known as rods and cones (Padgham & Saunders, 1975). The highest concentration of rods are located around the periphery of the retina. Cones on the other hand, are at their highest concentration in the center of the retina referred to as the fovea. Fowlkes has determined that the retina might be affected by a 24-hour clock similar to sleep patterns. Research has pointed to the possibility of the eye displaying greater sensitivity to light at specific times of the day ("Do we." 1983).

There exists in the human visual sense, a range of vision based on a conical area measured from a horizontal stare. This conical shape, which approximates 60-70 degrees from horizontal in all directions; up, down, left and right, is referred to as the cone of vision. The rods and cones located in the retina are fundamental in translating what the human sees in this cone of vision.

The rods and the cones differ in their ability to translate light energy into images. The difference is due to a photosensitive pigment known as rhodopsin and is easily affected by light causing it to 'bleach'. Because the rods are not sensitive to color interpretation, this type of vision is mainly used as a warning type of vision process that can be effective in low light situations. Vision at these low light levels is referred to as scotopic.

The cones on the other hand are used primarily for the interpretation of fine acuity and color vision. In the fovea, the cones are the most concentrated, there exists a difference in the ability of color interpretation. "Even within the fovea there are significant differences, as revealed, for example, by the threshold sensitivity to light of different wavelengths" (Wright, 1964, p.50). Zeki's (1984) discovery of specific visual areas containing numerous color-coded cells has increased the understanding of color vision physiology by providing 'mapping' of these cortical areas.

"The perception of colour necessarily implies the structures (of the eye) processes must exist which are capable of reacting differently according to the wavelength of incident light" (Wright, 1964, p.38). There is existing theory that the receptors in the eyes, rods and cones, are specialized in the interpretation of a particular radiation.

According to Wright there is reason to believe that there exists three types of cone receptors which process the whole gamut of color sensations. Originally this theory was developed by Thomas Young in 1802 and was supported by Hermann von Helmholtz 50 years later in 1852. Young theorized that only three radiations, red, violet (blue), and green were analyzed by the eye and signaled to the brain by these specialized cone receptors (Phadgham and Saunders, 1975). "Each nerve acts, not, as some have thought, by conveying to the mind the knowledge of the length of an undulation of light, or of its periodic time, but simply by being more or less affected by the rays which fall on it" (Evans, 1974, p.69). Beck (1975), defined the perception of surface color or the color of an object as the response of the visual system, that is the eye, to patterns of stimulation. Young theorized that when a derivation of hue such as magenta was "seen" that more than one (red and violet) of the cones were stimulated simultaneously and resulted in a mixing of the sensations in the correct proportions. This mixing theoretically, resulted in the color that is known as magenta. When all of the three types of cone receptors are stimulated equally the resultant outcome is white (Padgham & Saunders, 1975).

One simplistic possibility in assuming this type of mechanism behavior is that each of the cone receptors secrete three different photochemical substances. This in effect creates multiple variations of color responses (Wright, 1964). According to Sheppard there is still no definite experimental evidence of three and only three specific selective photochemicals (Sheppard, 1968).

Pirrene states in <u>Vision and the Eye</u> that "quantitatively, if not qualitatively, the laws of colour mixture are found to be different in different parts of the fovea" (Pirrene, 1967). The processing of the light by the eye to transmit it into a color interpretation will vary from individual to individual. Boynton (1979) credits the chief cause of variations among normal observers in interpreting light into color to pre-receptoral (before the retina) absorption differences.

Physiologist Hering proposed, unlike the Helmholtz theory, that there were three pairs of color processes. These consist of a black-white process, a red-green process and a yellow-blue process. This theory, an opponent process theory, is based on an antagonistic relationship between each pair. The relationship states that a color can have some red or some green but cannot have both red and green in the same place at the same time. In turn, the receptors can signal the brain either red or green but not both at once

(Bornstein & Marks, 1982).

Variances in the transmission of light through the optical media; cornea, lens, vitreous and aqueous humours, must be considered in order to evaluate color. "Account must first be taken of the light reflected by the surface of the cornea (which gives rise to the Purkinje images)" (Wright, 1967, p.87). Purkinje images, according to Wright, are the reflection of light off of the blood vessels in the cornea. If reflection of light off of blood vessels give rise to these visual effects is it possible that other reflections interrupt normal vision?

A study conducted by Teller (1981) demonstrated that there are clear age trends in the ability to discriminate selected hues from a background. At one month most of the infants failed to discriminate red, green or both stimuli from the yellow background. However, at 2 months of age more than half succeeded and at 3 months of age only one data set showed a failure by one infant to discriminate.

Bornstein (1976) states that infants encounter the visual world with a bias. An infant's perception and their memory for hue are organized prior to formal training or tuition. Infants, according to Bornstein, will recognize a hue after relatively short exposures and can remember a hue for at least short periods of time. This reaffirms previous research that hue memories can be thought of as a learned behavior as opposed to intuition or in-born. Fagan (1984) proposes that infants store information about a color used as a stimulus but is forgotten rapidly.

The difficulty that arises from infant hue discrimination is the control of the normal brightness variations that occur from hue to hue. The adult will perceive some particular hues as brighter even though the physical intensity is equal. This factor has been accounted for in research by equating different hues for brightness on the basis of adult judgments (Fagan, 1974).

As the eye ages there is an increased absorption of short wavelengths in the lens. According to Voke (1981) the ordinary aging process also leads to defects in blue perception as a result of the clouding of the lens.

Pickford (1973) reports in the British Journal of Aesthetics on color defective art students and the resultant effects on their work. Pickford derived from interviews and tests that an individual could be taught to overcome the inability to distinguish colors. Trevor-Roper (1970) suggests that paintings of many artists chose their colors based on some color defect in their vision. Certain artists as they age, have adjusted their palettes to compensate for the 'yellowing' of the lens.

The development of not only a color language but the ability to train and retain color information has been studied by Park and James. Concerned with the processing of spatial and color information by children, results show that "color memory is poorly retained unless a subject tries to learn it" (Park & James, 1983 , p.67).

Major criticism of the research conducted in color can be expressed on several grounds. First, that the colors that are used for the stimulus colors have not been clearly specified. Second, hue has been the only variable of interest and value and saturation have not been controlled. Third, a standard light source has not always been used. Last, few studies have used any type of screening process for color vision dysfunction (Gelineau, 1981). The above mentioned criticisms relate to the obvious gaps in the research conducted by color researchers.

The amount of research and writings on the physiology of the eye are quite extensive and except for a few discrepancies reflect the same information. Information on hue discrimination is limited to studies of infant's abilities to recognize color rather than the ability to highly discriminate. The interaction of the eye, light, pigment or coloring, and abilities must be considered in any research. However, some conclusions can be drawn from each of the separate studies that are available.

First, the structure of the eye itself is restrictive to the amount of light reaching the retina. Second, pigment theory of color is based on the ability of any colored surface to reflect those wavelengths in the visible spectrum that will 'color' that surface; blue surfaces reflect blue wavelengths. Third, the ability of an individual to train the eye to compensate for visual disorders exists.

If a colored surface, such as an iris, is reflecting wavelengths in a particular section of the spectrum, and if the lens and cornea restrict refraction of the light entering the pupil, can the resultant light reaching the retina be altered significantly? Can training in color alter the ability of individuals to discriminate colors? This exploratory study is designed to approach these questions and to arrive at some conclusions. The purpose of this study was to examine the relationships among individuals with different levels of color education, different eye colors, different college majors, and their ability to discriminate color. The following objective was used to guide the study:

1. To analyze whether a relationship exists among major course of study, level of color education, eye color, and the ability to discriminate hues.

METHODOLOGY

Research Design

The research design of this study was exploratory in nature and consisted of a factorial arrangement of treatments in a completely randomized design, (4x3x2). The purpose of this study was to investigate the relationships that might exist among the hue discrimination ability of individuals with different major courses of study, varying levels of color education and different eye colors. Exploratory studies are conducted for three main purposes; (1) to better understand a research topic, (2) to test the feasibility of undertaking a more focused study, and (3) to develop methods to be used in additional studies. Exploratory studies are utilized in social science research and are essential for "breaking new ground and adding new insights into topics of research" (Babbie, 1986, p.73). This study served as an exploratory study to break ground in an area of color research with little previous exploration.

Sample

The constructs of the research design are two fold; (1) a color test that can evaluate a subject's ability to discriminate hue and (2) a questionnaire to evaluate educational background and eye color. Selection of subjects included students enrolled at a midwestern university who were majoring in design related areas of art, architecture, interior design, and landscape architecture. Students in the four majors were selected for the sample from upper division courses that were offered during the same time of the day to allow for consistent daylight conditions. Upper division courses were used to assure a higher number of majors in the courses chosen. Two courses, one 3000 level and one 4000 level, were chosen from each area of study from the semester offerings to allow for a wider range in color courses taken in the subject's program of study. The final sample was 242 subjects consisting of 123 males (51%) and 119 females (49%). The sample included 75 architecture, 44 landscape architecture, 44 art, and 81 interior design students. Table VIII illustrates frequency distribution of the sample.

Insert Table VIII Here

Instrumentation

The Farnsworth-Munsell 100-Hue Test is designed as a test for color discrimination. It is designed to gather data that can be used "to separate persons with normal color vision into classes of superior, average and low color discrimination, and ..., to measure the zones of color confusion of color defective persons" (Farnsworth, 1957, p.2). The materials of the test include four wooden cases containing a total of ninety-three plastic caps. Each tray contains two fixed caps which are used as pilot caps. The two hues on these caps are repeated within the unattached caps which thereby reduces the total number of hues on the color caps to eighty-five.

Range of hues were identified from the ten principal hues of the Munsell system. Each range consisted of the disks associated with a principal Munsell hue. For example, Range C consisted of all the disks associated with Munsell yellow. The disks of the test assigned to the yellow range or Range C would be numbers 14 through 22. Range A represents red, B yellow-red, C yellow, D green-yellow, E green, F blue-green, G blue, H purple-blue, I purple, and J red-purple.

The Farnsworth-Munsell 100 Hue Discrimination Test was administered under standardized daylight illumination. Natural daylight was used for the testing procedure according to administration regulations under illumination from a northern sky. Sky conditions were lightly to moderately overcast and approximated 6500 degrees Kelvin. To control for lighting variations, a light meter was used to determine proper light conditions. In addition all artificial illumination was eliminated from the testing area. Testing of the participants, which occurred during scheduled class times, was limited to the hours between eleven-thirty and one-thirty. This allowed for consistent daylight conditions.

During the examination period the administrator was seated directly opposite the subject. The lighting for the examination was from an angle of illumination of about 90 degrees and the viewing angle of the trays was about 60 degrees. Letting the trays set within the participant's cone of vision (60 degrees) allowed for better visual acuity.

In addition to the hue instrument, each participant was asked to complete a demographic questionnaire to obtain information concerning eye color, educational status, major, and coursework. Information concerned with both previous or current enrollment in courses identified as having some aspect of color education in the subject matter was obtained from the questionnaire. These courses included those that had instruction in theoretical information, manipulation of light, manipulation of pigments of all kinds, and manipulation of all types of materials. Included were such diverse courses as theatrical lighting, oil painting, plant materials, and weaving. Additional courses listed in the questionnaire included those beyond the requirements of the four majors for the completion of their degree programs.

Because this study was concerned only with subjects that were majoring in four aesthetic based courses of study it is assumed that there had been color training in their education at some time. Levels of color education were determined by number of credit hours of completed courses by participants during their education. The two levels were signified by either a low or high label. Low level color education constituted any participant who had completed 18 or less credit hours of color courses. High level constituted any participant who had completed 19 or more credit hours of color coursework.

Eye color of the participant was obtained from the questionnaire by asking for the individual's eye color according to their driver's license. This method was chosen for determining eye color based on a valid and legal documentation process.

Procedure

Administration of the test was repeated in the same manner for each subject and entailed the following testing procedure. Case 1 was opened and placed before the subject on a surface that had been covered with a white cloth. The tray or panel had previously been arranged so that the loose caps were in random order in the upper lid. The tray with the two fixed caps was adjusted so that it was nearest to the subject. The subject was then instructed as per the instructions accompanying the test. A subject was allowed as much time as was necessary to arrange the caps. It was most important that the arrangement be to their satisfaction. When the subject had completed a tray the process was repeated with the remaining three trays.

The Farnsworth-Munsell test was scored in three separate procedures. Each subject was scored for 1) an overall total test score, 2) on each of the four trays, and 3) on the ten ranges of hues of the test. Scores were calculated from a placement-displacement criteria. If a disk had a correct placement a zero value was assigned. Displacement of a disk resulted in an absolute value of the difference between correct and incorrect placement value. For example, if disk 3 was placed in the disk 1 position, then a value of 2 was added to the score. Low scores on the test or any portion of the test were preferred.

Data Analysis

To measure the relationships that exist among hue discrimination abilities of individuals majoring in different aesthetic areas of study with different levels of color education and different eye colors, multivariate analysis of variance (MANOVA) was utilized for data analysis of the research variables. Prior to final analysis of the sample, preliminary data analysis was dictated by sample and data collection.

Data were first collected at a midwestern university in Spring semester of 1983. The sample size of this data set was found to be small for analysis, therefore additional data were collected in the Fall semester of 1989. Because data collection occurred at a six year interval and there were unusual gender distribution patterns of the samples, analysis of the samples was conducted to determine similarities and differences between the samples.

First, analysis was conducted to evaluate whether gender distribution was affecting the study. Architecture and interior design were of primary interest since the architecture portion of the sample was primarily male and interior design portion was primarily female. In Sample I, 49 percent of the total sample size was male an 51 percent was female. Of the 32 architecture students in the sample, 30 were male. Of the 41 interior design students in Sample I 36 were female. In Sample II, 30 of the 43 architecture students in the sample were male and 34 of the 40 interior design students in the sample were female. It was thought that the difference in gender distribution in architecture and interior design could skew the results of the study.

Analysis of variance was used to analyze Sample I, Sample II, and the combined samples. On both individual samples and the merged sample, gender was not significant among majors, (F (4, 237) = 2.12, p = .1469).

Second, analysis of the two samples was conducted to evaluate if any significant differences existed between the two. In order to evaluate the two samples for differences and similarities, a dummy variable was first created called Study. Multiple regression analysis was then performed and resulted in a multiple $R^2 = .31$. An F test was then conducted on the study variables and all study variable interactions. No significant differences were found between the two samples, F (7, 222) = 1.067, p =.3857. Since no significant differences existed between the samples they were merged to form one sample.

RESULTS AND DISCUSSION

Multivariate analysis of variance (MANOVA) for the independent variables (major, color education and eye color) and for all scoring procedures (total, trays, and ranges) indicated interesting findings. Wilk's Criterion, used as the hypothesis test for no overall effect on trays, indicated a significance for color education with an F (4,215) = 4.83. p = .0009. Wilk's Criterion also indicated a significance for range scores on color education, F (10,209) = 2.63, p = .005. Further findings are described below.

Total Score

Analysis of variance was calculated for total score on the independent variables. No interactions were indicated for total score on major by color education, eye color by color education, major by eye color, or major by eye color by color education. For major and eye color, no main effects were indicated. Color education as a main effect was significant with an _F_ (1, 218) = 24.30, _p_ = .0001 (see Table IX).

Tray Scores

Analysis of variance of tray scores was performed on the study variables. Color education was significant as a main effect on all four trays as indicated in Table X. All trays were significant at a p-value of .001 or less. Calculated _F_-values were, _F_ (1, 218) = 18.06, _p_ = .0001; _F_ (1, 218) = 14.07, _p_ = .0002; _F_ (1, 218) = 10.51, _p_ = .0014; and _F_ (1, 218) = 17.62, _p_ = .0001 respectively for Trays 1 through 4.

Insert Table X Here

Of the interactions tested on tray scores only two were significant. Both Tray 2 and Tray 4 were significant for major by eye color. Calculated F-values for these trays were _F_ (6, 218) = 2.89, _p_ = .0099 and _F_ (6, 218) = 2.27, _p_ = .0380 respectively.

Post hoc procedures were conducted using Newman-Keuls for the significant interactions. Remembering that a low score was preferred, results from these procedures on Tray 2 indicated that architecture students with green eyes scored significantly higher than either architecture students with brown or blue eyes. Interior design students with green eyes also scored significantly higher than those with blue or brown eyes. In direct contrast landscape architecture students with green eyes scored significantly lower than either of the two eye colors. Green-eyed art students also scored significantly lower than art students with students with blue eyes. Neither students with blue or brown eyes in any of the majors were significantly different from each other although in two of the four trays blue and brown scored lower; architecture and interior design. Landscape architecture and art students with blue and brown eyes scored significantly higher than green-eyed students.

Table XI illustrating results from Newman-Keuls procedure on Tray 4 indicated significant differences in majors with both blue and brown eyes. Green-eyed students in all majors indicated no significant differences. Students with blue eyes majoring in landscape architecture scored significantly higher than those in interior design or architecture but not significantly higher than art students.

Insert Table XI Here

Brown-eyed students also indicated a significant difference among majors. Landscape architecture scored significantly higher than art students with the same eye color but not significantly different than either interior design or architecture students.

Range Scores

Multiple analyses of variance of range scores were calculated for major, color education and eye color. Table XII references all calculated F values and p-values. Major as a main effect was significant for Range E, the green portion of the spectrum (F (3, 218) = 3.51, p = .0161). Color education as a main effect was significant for seven of the ten ranges. Range D through Range J, which represent the green-yellow through the red-purple hues of the spectrum are those that were significant at p-values of .01 or less.

Insert Table XII Here

Interactions indicating significance were eye color by color education and major by eye color. Eye color by color education was significant for Range E (green),(F (2, 218) = 3.16, p =.0443). Newman-Keuls procedure performed on Range E interaction indicated significant differences between a low level of color education and a high level of color education for both blue and brown eyes but not students with green eyes. Scores on Range E were significantly lower with more color coursework with the exception of green-eyed students (see Table XII).

Interactions between major by eye color were significant for both Range D (green-yellow) and Range I (purple) with $\underline{F}$ (6, 218) = 3.13, $\underline{p}$ = .0058 and $\underline{F}$ (6, 218) = 3.23, $\underline{p}$ = .0046 respectively. Multiple range tests, Newman-Keuls, were performed on both interactions. Results of the post hoc procedures on Range D indicated a significant difference among eye colors for both architecture and landscape architecture. Landscape architecture students with green eyes scored significantly lower than either those students with blue or brown eyes. Architecture students also indicated a significant difference among eye color. Again green-eyed students showed a significant difference except that they were significantly higher scoring than those with blue or brown eyes. Neither art or interior design students indicated significant differences among eye colors. Table XIII condenses the results from this procedure.

The results of Newman-Keuls procedure on Range I (purple) indicate significance again for two of the four majors; art and interior design. Blue-eyed art students scored significantly higher than those students with green

Insert Table XIII Here

eyes. Art students with brown eyes were not significantly different from either blue-eyed or green-eyed students. Interior design students also indicated a significant differences among eye colors. Green-eyed students scored significantly higher than either the blue-eyed or brown-eyed students.

SUMMARY AND CONCLUSIONS

Because this was an exploratory study, this study does not draw conclusions but describes the findings of the study and proposes recommendations for further research. Of the variables used in the research, eye color had not been utilized in previous studies. Results of the use of this variable indicated some interesting findings.

Of the three different eye colors studied in this research, the relationship between green-eyed students and hue discrimination was most pronounced. Those students with green eyes in landscape architecture scored better on the hue discrimination test in the green-yellow area of the spectrum than any of the other majors and eye colors. However, students majoring in interior design with green-eyes scored last on the test of the groups in this particular color region. Possibly, the concentration of work with the green palette by landscape students could account for better (lower) scores than other groups. Or, the better ability in the green area of the spectrum shown by these individuals led them to select landscape architecture as a major. Although conclusions cannot be drawn concerning eye color and visual color abilities, the interaction relationship of a particular hue and better acuity would indicate a need for further research.

The physiology of the eye is complex, but what is known is that light must pass through multiple layers of materials before it reaches the final receptors of rods and cones. In doing so the action of the wavelength could be interrupted by the reflections off of the iris such as Wright (1967) suggests that Purkinje images are reflections off of blood vessels of the eye. Closer scrutiny of this variable is warranted to investigate the interaction of eye color and the role it plays, if any, in the perception and discrimination of color.

The pattern of means of variable interactions of the purple portion of the spectrum echo those of the green range. Art students with blue eyes and interior design students with green eyes appear to have the most difficulty discriminating among the purple hues. Purple, which is classified as a cool color, is composed of a mixture of blue and red according to Munsell's (1929) theory. Again a relationship is indicated between a eye color and a particular hue. This time the hue and eye color are in the blue region of the spectrum with lower discriminate ability scores associated with the hue and eye color. Association with a physical characteristic is not possible without further study. However, because physiological theories of color vision are ever changing, a relationship between hue discrimination and iris color should continue to be studied as part of the receptor process that Dawson (1963) describes as the modification process of iris as to the amount of light entering eye.

These data indicate that a relationship exists between the levels of color education and the ability of these students to discriminate hues. The results, of a relationship between color education and hue discrimination ability, support Park and James' (1983) study of color memory retention. Park and James found that color memory was improved by the process of 'trying' to retain color through learning. Results from this exploratory study are consistent with Pickford's (1973) case study that color deficiencies can be compensated for over periods of time.

Of the ten hues tested, seven indicated a relationship with the levels of color education. Red, yellow-red, and yellow, the warm colors of the spectrum, indicated no relationship with the high level of color content coursework. No previous research has indicated particular reasons why this would occur. Subsequently, research directed toward these warm hues needs to be conducted to examine whether warm hues are 'learned' at a different time and rate than cool colors.

No significant patterns by major were indicated in this study. The most notable relationship, however, indicated by the results of this study was that of the landscape architecture students and their ability to discriminate hues on Tray 4. These students scored significantly lower (better discrimination) on this tray than the other three. Again, the colors represented in this tray were those that possibly were not used frequently by these majors. Blue-purple, purple, and red-purple are hues not generally associated with the palette of the landscape architect. Other majors, more likely to use these hues, indicated no significant differences for this tray and scored considerably better on this portion of the test.

Outcomes of this research indicated that further studies should be conducted on these variables. If color education levels are related with hue discrimination ability, the relationship should be studied to determine how and to what degree the variables are connected. Control of a specific learning experience is proposed for a follow-up study. The impact on curriculum in the aesthetic majors as well as those outside the design areas should be noted if a relationship between hue discrimination ability and color education exposure can be defined. Possible outcomes of knowledge of a relationship could be that of proposed additional coursework or projects for the curriculums that focus on color alone, possibly allowing this additional exposure take place over the four or five years that a student is enrolled in their chosen major.

Although eye color was not significant as a main effect, it should not be discarded as a variable in further studies. Interactions with both color education and major indicate a possible relationship that should not be ignored. Further studies should involve a closer classification of eye color to help pin-point hue discrimination and eye color relationships.

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TABLE VIII

FREQUENCY DISTRIBUTION OF MAJOR, EYE COLOR, AND COLOR EDUCATION

	EYE COLOR			
	BLUE	BROWN	GREEN	TOTAL
	n	n	n	n
ARCHITECTURE				
LOW	12	13	10	35
HIGH	12	15	13	40
LANDSCAPE ARCHITECTURE				
LOW	8	6	7	21
HIGH	9	8	6	23
ART				
LOW	7	2	7	16
HIGH	10	7	9	26
INTERIOR DESIGN				
LOW	5	4	7	16
HIGH	28	15	22	65
TOTAL N	91	70	81	242

TABLE IX

ANOVA OF TOTAL SCORE ON MAJOR, COLOR EDUCATION, AND EYE COLOR

SOURCE	df	f	p-value
MAJOR	3	.48	.6961
EYE COLOR	2	.04	.9630
COLOR EDUCATION	1	24.30	.0001
MAJOR BY COLOR EDUCATION	3	1.30	.2743
EYE COLOR BY COLOR EDUCATION	2	.22	.8032
MAJOR BY EYE COLOR	6	.73	.6294
MAJOR BY EYE COLOR BY COLOR EDUCATION	6	.74	.6185

* INDICATES SIGNIFICANCE AT $p \geq .01$

TABLE X

ANOVA OF TRAY SCORES ON MAJOR, COLOR EDUCATION, AND EYE COLOR

		TRAY 1		TRAY 2		TRAY 3		TRAY 4	
SOURCE	df	F	p-value	F	p-value	F	p-value	F	p-value
MAJOR	3	0.36	0.7813	0.65	0.5858	0.85	0.4705	1.70	0.1686
EYE COLOR	2	0.00	0.9976	0.52	0.5954	1.69	0.1864	0.02	0.9800
COLOR EDUCATION	1	18.06 *	0.0001	14.07 *	0.0002	10.51 *	0.0014	17.62 *	0.0001
MAJOR BY EYE COLOR	6	0.46	0.8407	2.89 *	0.0099	1.04	0.3983	2.27 *	0.0380
EYE COLOR BY COLOR EDUCATION	2	0.22	0.8015	0.95	0.3865	1.33	0.2657	2.82	0.0618
MAJOR BY COLOR EDUCATION	3	0.91	0.4380	0.12	0.9455	1.83	0.1426	1.76	0.1549
MAJOR BY EYE COLOR BY COLOR EDUCATION	6	0.89	0.5027	0.86	0.5235	0.93	0.4752	0.80	0.5700

* INDICATES SIGNIFICANCE AT $p \geq .05$

TABLE XI

NEWMAN-KEULS MULTIPLE RANGE TEST FOR TRAYS 2 AND 4 ON MAJOR BY EYE COLOR

TRAY 2

ARCHITECTURE		LANDSCAPE ARCHITECTURE		ART		INTERIOR DESIGN	
EYE COLOR	MEAN	EYE COLOR	MEAN	EYE COLOR	MEAN	EYE COLOR	MEAN
GREEN	10.1304 a	BLUE	11.0588 a	BLUE	10.7059 a	GREEN	11.3103 a
BROWN	7.5000 b	BROWN	9.0000 a	BROWN	8.0000 ab	BLUE	8.6667 b
BLUE	7.0000 b	GREEN	5.0769 b	GREEN	6.9375 b	BROWN	8.2105 b

TRAY 4

BLUE		BROWN		GREEN	
MAJOR	MEAN	MAJOR	MEAN	MAJOR	MEAN
LANDSCAPE ARCHITECTURE	10.6471 a	LANDSCAPE ARCHITECTURE	9.6429 a	LANDSCAPE ARCHITECTURE	9.0000 a
ART	10.2353 ab	ART	7.2632 ab	ART	7.2609 a
INTERIOR DESIGN	6.1818 b	INTERIOR DESIGN	6.8214 ab	INTERIOR DESIGN	6.4615 a
ARCHITECTURE	5.4583 b	ARCHITECTURE	5.2222 b	ARCHITECTURE	6.0625 a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

TABLE XII

ANOVA OF RANGE SCORES ON MAJOR, COLOR EDUCATION, AND EYE COLOR

SOURCE		A RED		B YELLOW-RED		C YELLOW		D GREEN-YELLOW		E GREEN	
	df	F	p-value	F	p-value	F	p-value	F	p-value	F	p-value
MAJOR	3	1.75	.1584	.80	.4968	0.57	.6345	1.04	.3765	3.51 *	.0161
EYE COLOR	2	1.03	.3586	0.66	.5193	0.96	.3844	1.34	.2644	0.22	.8033
COLOR EDUCATION	1	2.63	.1063	2.77	.0972	2.18	.1411	10.18 *	.0016	17.24 *	.0001
MAJOR BY COLOR EDUCATION	3	0.42	.7409	1.28	.2833	0.77	.5133	0.77	.5118	0.06	.9792
EYE COLOR BY COLOR EDUCATION	2	0.24	.7891	0.39	.6764	0.18	.8385	1.10	.3341	3.16 *	.0443
MAJOR BY EYE COLOR	6	0.79	.5818	0.35	.9120	1.36	.2307	3.13 *	.0058	2.01	.0659
MAJOR BY EYE COLOR BY COLOR EDUCATION	6	0.19	.9785	0.23	.9650	0.35	.9094	1.00	.4229	0.56	.7584

* INDICATES SIGNIFICANCE AT $p \geq .05$

TABLE XII, continued
ANOVA OF RANGE SCORES ON MAJOR, COLOR EDUCATION, AND EYE COLOR

SOURCE	F BLUE-GREEN		G BLUE		H PURPLE-BLUE		I PURPLE		J RED-PURPLE	
df	F	p-value	F	p-value	F	p-value	F	p-value	F	p-value
MAJOR										
3	0.21	.8917	0.63	.5950	0.20	.8948	1.75	.1574	0.46	.7116
EYE COLOR										
2	1.32	.2691	0.67	.5128	.02	.9814	0.20	.8182	0.00	.9973
COLOR EDUCATION										
1	8.35 *	.0042	5.27 *	.0226	7.44 *	.0069	14.78 *	.0002	17.78 *	.0001
MAJOR BY COLOR EDUCATION										
3	1.71	.1659	2.27	.0810	1.62	.1865	2.41	.0682	0.66	.5804
EYE COLOR BY COLOR EDUCATION										
2	0.85	.4308	0.56	.5713	.04	.9569	2.00	.1378	0.82	.4418
MAJOR BY EYE COLOR										
6	0.55	.7662	1.00	.4279	1.82	.0954	3.23 *	.0046	0.38	.8915
MAJOR BY EYE COLOR BY COLOR EDUCATION										
6	0.96	.4535	0.93	.4710	0.42	.8667	1.20	.3090	0.98	.4399

* INDICATES SIGNIFICANCE AT $p \geq .05$

TABLE XIII

NEWMAN-KEULS MULTIPLE RANGE TEST FOR RANGE E ON EYE COLOR BY COLOR EDUCATION

BLUE	MEAN	BROWN	MEAN	GREEN	MEAN
LOW	9.0938 a	LOW	9.68 a	LOW	7.26 a
HIGH	6.5763 b	HIGH	6.33 b	HIGH	7.16 a

MEANS WITH THE SAME LETTERS ARE NOT SIGNIFICANTLY DIFFERENT

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APPENDIXES

APPENDIX A

DEMOGRAPHIC QUESTIONNAIRE

Demographic Questionnaire

1. Student Number ----------------

2. Age

   1. 17-20 ---------
   2. 21-23 ---------
   3. 24-27 ---------
   4. 28-31 ---------
   5. 32-35 ---------
   6. 36 and over ---------

3. Sex

   1. Male ------
   2. Female -----

4. Educational Status

   1. Freshman (0-20 cr. hrs.) ----------
   2. Sophomore (30-44 cr. hrs.) ----------
   3. Junior (45-74 cr. hrs.) ----------
   4. Senior (75 or more cr. hrs.) ----------
   5. Graduate ----------
   6. Other (please specify) --------------------

5. Major

   1. Architecture ----------
   2. Landscape Architecture ----------
   3. Landscape Construction ----------
   4. Art ----------
   5. Interior Design ----------
   6. Other (please specify) --------------------

6. Minor (if any)

   1. Please specify -----------------------------

7. Were you born in this country?

   1. No -----
   2. Yes -----

8. If yes, in which state were you born? ---------------

9. If you answered "no" to question #7, in which country were you born? --------------------

10. How old were you when you entered the United States?

    1. 0-5 years ----------
    2. 6-10 years ----------
    3. 11-15 years ---------
    4. 16-20 years ----------
    5. 21 and older ----------

11. How long have you lived in the United States?

    1. 0-5 years ----------
    2. 6-10 years ----------
    3. 11-15 years ----------
    4. 16-20 years ----------
    5. 21 and up ----------

12. What other states other than Oklahoma have you lived in for a year or more?

    ----

13. Have you had any educational experiences in countries other than the United States? If so, please indicate in which countries you were educated, how many years you lived there and your age at the beginning of experience?

Country	Years	Age
---------------------	------	-------
---------------------	------	-------
---------------------	------	-------
---------------------	------	-------

14. List the countries in which you have traveled for two or more weeks.

    ----

15. According to your driver's license, what color are your eyes?

    ----

16. Do you need to wear prescription glasses?

    1. No -----
    2. Yes -----

17. Do you wear?

    1. Glasses -----
    2. Contacts -----

18. If you need to wear prescription lenses, are you wearing them now?

    1. No -----
    2. Yes -----

19. Are you?

    1. Nearsighted? -----
    2. Farsighted? -----

20. Do you know your eye prescription?

    1. No -----
    2. Yes -----

21. If yes, please specify

    ----

22. Do you have or have your ever had any eye diseases or injuries?

    1. No -----
    2. Yes -----

23. If yes, please specify

    ----

24. Are you enrolled in or have you completed any of the following courses at OSU (or similar courses if a transfer student). Check the appropriate courses.

    ----- 1. ARCH 1216 - Architectural Design Studio I. Architectural graphics and design fundamentals.

    ----- 2. ARCH 2003 - Architecture and Society. Design planning and building considered in their social and aesthetic contexts.

    ----- 3. ARCH 2100 - Architectural Studies. Beginning studies in graphics and design in architecture.

    ----- 4. ARCH 2116 - Architectural Design Studio II. Problems in architectural design.

----- 5. ARCH 2216 - Architectural Design Studio III.
Problems in architectural design.

----- 6. ARCH 3117 - Architectural Design Studio IV.
Problems in architectural design.

----- 7. ARCH 4117 - Architectural Design Studio V.
Problems in architectural design.

----- 8. ARCH 4217 - Architectural Design Studio VI.
Problems in architectural design.

----- 9. ARCH 5119- Architectural Design and Development.
Design and detailed development of a major architectural project integrating all aspects of architecture and related disciplines in a professional manner and milieu.

----- 10. ARCH 5217 - Architectural Design Studio VII.
Problems in architectural design.

----- 11. ARCH 5233 - Advanced Architectural Lighting Design.
Lighting applications in contemporary architectural design, including offices, schools, churches, health care facilities, etc. Principles applied to a design of students choice.

----- 12. ARCH 6117 - Architectural Design Studio VIII.
Problems in architectural design.

----- 13. ART 1113 - Drawing II.
Objective and subjective approaches to visual problem solving in a variety of black and white and color media. The analysis and manipulation of form, light, space, volume and the formal aspects of perspective.

----- 14. ART 1203 - Design I.
An introduction to visual problem solving. Organization of the two-dimensional plane using the elements and principles of design: line, shape, value, texture and color. Use of black and white and color media.

----- 15. ART 1803 - Introduction to Art.

An introduction to the analysis and interpretation of visual arts. Visual, emotional, and intellectual aspects of art in painting, sculpture, printmaking, and architecture.

----- 16. ART 2203 - Three Dimensional Design.

Exploration of three dimensional form and space stressing organization of design elements, development of concepts and manipulation of materials. Investigation of linear space, modular ordering, mass/volume and color through projects of a conceptual and applied nature.

----- 17. ART 2213 - Design II.

Color theories and their application to visual problem solving, distinction between pigment and light and between additive and subtractive color mixing. The nature and properties of color, its expressive qualities, symbolic potential, and psychological impact.

----- 18. ART 3123 - Beginning Painting.

The development of skills in oil painting stressing form and content, visual perception and individual expression. Technical instruction applicable to individual problems and needs.

----- 19. ART 3133 - Watercolor Painting.

The development of skills in watercolor painting stressing form and content, visual perception and individual expression. Structured assignments in color mixing, wet-on-dry techniques, brush handling, paper supports and surface manipulation.

----- 20. ART 3503 - Ceramics

Methods of clay preparation, hand building, wheel forming methods, methods of decoration and glazing, firing and kiln construction. Involvement with ceramic materials and processes.

----- 21. ART 4400 - Graphic Design II.

Employment of skills gained in preparatory courses such as lettering, illustration and photography. Advertising design and publication art for printed media.

----- 22. CTM 2113 - Applied Design in the Clothing Industry.
Appreciation of art elements and design principles; development of skill in application of design within various segments of the clothing industry.

----- 23. CTM 3002 - Professional Image and Dress.
Role of appearance and dress in creating a professional image for men and women. Figure and wardrobe analysis, professional clothing needs, individualized clothing decisions.

----- 24. CTM Fashion Sketching.
Principles and techniques of sketching in the fashion field.

----- 25. CTM Merchandise Display Essentials.
Study and application of principles and practices in arranging and displaying merchandise for commercial and educational purposes. Supervised working experience working with merchandise from retail stores.

----- 26. CTM 4363 - Fashion Promotion Media.
Advertising and other special-purpose media used in the promotion of fashion merchandise. Study and application of procedures used in planning, evaluating, and directing effective sales promotional activities.

----- 27. CTM 4403 - Creative Costume Design.
Application of design principles and construction techniques in the development of original designs.

----- 28. HORT 1013 - Principles of Horticulture and Landscape Design.
Horticulture principles and practices; basics of landscape design; characteristics and use of horticulture plants; scope and development of the horticultural industry.

----- 29. HORT 2652 - Basic Floral Design.
Fundamentals of floral arrangements and design for the home and the retail shop; basic skills useful to flowershop employment and operation.

----- 30. HIDCS 1123 - Graphic Design for Interiors.
Drafting and visual communication techniques related to interiors.

----- 31. HIDCS 2213 - Presentation Techniques for Interior Design.
Two and three dimensional presentation techniques using various media and formats.

----- 32. HIDCS 2313 - Introduction to Interior Design.
Basic interior design theory including aesthetic, social, and economic aspects of the housing environment in relation to needs, values and goals of individuals and families.

----- 33. HIDCS 3213 - Interior Design Studio I: Residential.
Studio course utilizing the design process in the analysis, space planning and construction techniques involved in the design of residential spaces to achieve efficient use of energy and space.

----- 34. HIDCS 3233 - Heritage of Interiors I.
Residential architecture and furnishings prior to and including the 19th century with emphasis on the periods which have greatly influenced housing and interior design.

----- 35. HIDCS 3253 - Environmental Design for Interior Spaces.
Design factors and human performance criteria for lighting, acoustics, and thermal/atmospheric comfort as they relate to the practice of interior design.

----- 36. HIDCS 3343 - Design and Space.
Creative exploration of three dimensional spaces in interior design.

----- 37. HIDCS 3363 - Interior Design Studio II: Contract.
Studio course utilizing the design process in the analysis of office planning including systems and specifications.

----- 38. HIDCS 42934 - Interior Design Studio III: Commercial and Residential.
Studio course utilizing the design process in the analysis and planning of commercial, institutional and retail environments with emphasis on materials, codes and accessibility.

----- 39. LA 3002 - Advanced Landscape Architectural Delineation.
The application of multimedia presentation and delineation techniques to more complex plans, drawings and programs.

----- 40. LA 3773 - Landscape Architectural Design I.
Application of landscape architectural design theory to the planning and design of outdoor spaces and elements for best human use and enjoyment.

----- 41. LA 4013 - Landscape Architectural Design II.
Continuation of LA Design I with an emphasis on design methodologies.

----- 42. LA 4023 - Landscape Architectural Design III.
Complex site developments with emphasis on landforms and structures.

----- 43. LA 4024 - Landscape Architectural Design IV.
Large scale sites with an emphasis on arrangement and design of landscape elements as they relate to health, safety and welfare as well as functional and aesthetic qualities.

----- 44. LA 4033 - Landscape Planting-Design.
Plants in the landscape as aesthetic and functional elements. Environmental enhancement by and for plants. Preparation of planting sketches, plans and specifications.

----- 45. LA 4573 - Recreational Design.
Design concept development for large scale recreation areas or systems with an emphasis on natural resources.

----- 46. LA 5024 - Landscape Architectural Design V.
Complex landscape architectural project design at the community level including subdivision of land, park systems and land use relationships.

----- 47. TH 2613 - Technical Production I.
Elementary techniques of stagecraft, lighting and costume for the stage. Emphasis on basic skills. Practical experience preparing for Departmental productions.

----- 48. TH 2623 - Technical Production II.

Intermediate course in costume, stagecraft and stage lighting. Refinement of basic technical skills, introduction of design and conceptualization principles. Practical experience preparing for departmental productions.

----- 49. TH 3442 - Stagecraft Projects.

Extended laboratory for those with special abilities and interests in stagecraft.

----- 50. TH 3773 - Stage Make-up.

Application and relationship to character. Facial anatomy, prosthesis, wigs and hair. Laboratory work for preparing for productions.

----- 51. TH 4413 - Lighting for Theatre and Television.

Stage lighting design, elementary electricity, physics of lighting instruments. Practical experience in lighting in preparing for productions.

----- 52. TH 4420 - Summer Theatre.

Workshop in all phases of theatre production: acting, stagecraft, lighting makeup, publicity, box office, etc.

----- 53. TH 4433 - Scene Design for Theatre and Television.

The designer's approach to the script; execution of sketches, models and working drawings.

----- 54. TH 4813 - Stage Costume Design.

Basic treatment of costume design: practical application through design sketches. Style of stage costume. Practical experience preparing for departmental productions.

APPENDIX B

SUPPORTIVE TABLES

RANGE OF HUES FOR SCORING OF FARNSWORTH MUNSELL 100 HUE DISCRIMINATION TEST

RANGE A	RED
RANGE B	RED-YELLOW
RANGE C	YELLOW
RANGE D	GREEN-YELLOW
RANGE E	GREEN
RANGE F	BLUE-GREEN
RANGE G	BLUE
RANGE H	PURPLE-BLUE
RANGE I	PURPLE
RANGE J	RED-PURPLE

FREQUENCY DISTRIBUTION OF MAJOR, EYE COLOR, AND COLOR EDUCATION

	EYE COLOR			
	BLUE	BROWN	GREEN	TOTAL
ARCHITECTURE	n	n	n	n
LOW	12	13	10	35
HIGH	12	15	13	40
LANDSCAPE ARCHITECTURE				
LOW	8	6	7	21
HIGH	9	8	6	23
ART				
LOW	7	2	7	16
HIGH	10	7	9	26
INTERIOR DESIGN				
LOW	5	4	7	16
HIGH	28	15	22	65
TOTAL N	91	70	81	242

MEANS OF TRAY SCORES FOR MAJOR BY EYE COLOR

	EYE COLOR					
MAJOR	BLUE	n	BROWN	n	GREEN	n
TRAY 2						
ARCHITECTURE	7.0000	24	7.5000	28	10.1304	23
LANDSCAPE ARCHITECTURE	11.0588	17	9.0000	14	5.0769	13
ART	10.7059	17	8.0000	9	6.9375	16
INTERIOR DESIGN	8.6667	33	8.2105	19	11.3103	29
TOTAL N		91		70		81
TRAY 4						
ARCHITECTURE	5.4583	24	6.8214	28	7.2609	23
LANDSCAPE ARCHITECTURE	10.6471	17	9.6429	14	6.4615	13
ART	10.2353	17	5.2222	9	6.0625	16
INTERIOR DESIGN	6.1818	33	7.2632	19	9.0000	29
TOTAL N		91		70		81

MEAN SCORES FOR MAJOR BY EYE COLOR

RANGE D

	EYE COLOR					
MAJOR	BLUE	n	BROWN	n	GREEN	n
ARCHITECTURE	3.1667	24	3.1429	28	5.3043	23
LANDSCAPE ARCHITECTURE	5.5882	17	4.2857	14	2.8461	13
ART	5.9412	17	3.4444	9	2.8125	16
INTERIOR DESIGN	4.4242	33	4.0526	19	5.8276	29
TOTAL N		91		70		81

VITA

Pamela Kay Evans

Candidate for the Degree of

Doctor of Philosophy

Thesis: HUE DISCRIMINATION AS RELATED TO EYE COLOR AND COLOR EDUCATION: AN EXPLORATORY STUDY

Major Field: Home Economics

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