

THE EFFECT OF TEXTURE ON ADDITIVE COLOR
MIXTURE IN FABRIC

Thesis for the Degree of M. A.

MICHIGAN STATE UNIVERSITY

Gay Wright Vela

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ABSTRACT

THE EFFECT OF TEXTURE ON ADDITIVE COLOR MIXTURE IN FABRIC

by Gay Wright Vela

Few studies have been reported on the effects of texture on color. The purpose of this study was to determine what effect a sheen and a non-sheen textured yarn would have on additive color mixture in fabric. This study of the relation between texture and color was undertaken to aid designers of interiors and fabrics to better understand the results which occur when the factor of texture is introduced to an additive color mixture in fabric.

Data were taken from 300 specially woven samples with designed controls to allow the two types of texture to be the variants. One variant was a non-sheen cotton mat ratiné texture and the other variant was a rayon sheen ratiné texture. The two textured yarns and the plain control yarn were matched to Munsell's ten basic colors.

Two groups of samples were selected for this study. In one group the warp and filling yarns were of complementary colors and in the other group the two colors used were two steps apart on the Munsell color wheel.

Gay Wright Vela

Three qualified judges observed the samples macroscopically and recorded their impressions in terms of comparative notations, using the Munsell notation system for hue, value, and saturation changes. These comparisons were recorded on tables and graphs which were then used for analysis.

The textured samples were compared to the control samples, the two textured groups were compared with each other, and the two harmony groups were compared. All of these comparisons were then analyzed to determine how much change occurred.

The control groups, woven from complementary colors, additively blended to approximate neutral gray. Samples woven with colors located two steps apart on the color wheel blended to a color about half way between the two yarn colors as was expected. However, when texture was introduced, the hue of the sample favored the hue of the textured yarn in both harmony groups.

Value comparisons showed that textured yarns which were dark in value caused the samples to seem darker in value. When the textured yarns were light in value, the samples appeared lighter in value than the control samples.

When the two harmony groups were compared, the rayon texture generally was found to cause the samples to seem lighter in value than the control samples. The cotton texture generally

Gay Wright Vela

caused the samples to appear darker in value than the control samples.

When the samples were compared for saturation changes, about half appeared to remain at the same saturation level as the control samples. In the half that differed, the rayon texture caused the samples to seem brighter than the control samples and the cotton texture caused the samples to appear duller than the control samples.

In general this study indicated that texture changes the hue of the fabric to favor the hue of the textured yarn. Texture also changes the value and saturation to closely resemble the inherent value and saturation of the textured yarn.

THE EFFECT OF TEXTURE ON ADDITIVE COLOR
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By

Gay Wright Vela

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TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION	1
Color and Its Form	1
The Problem	2
The Relationship of this Study to Other Related Studies	2
The Specific Objectives of this Study	3
The Research for this Study	5
The Value of this Research	7
II. REVIEW OF THE LITERATURE	8
Well-known Color Scientists	8
Types of Color Mixture	12
Does the Term "Additive" Apply to the Mixing of Different Colored Yarns?	13
Luster and Texture of Yarns	18
How Weaves Affect Samples	20
Choosing between the Mechanical or Human Eye Method of Judging Samples	21
Citing Academically Accepted Color Judging Done by the Human Eye	26
The Influence of Illumination in Judging Distance Judges Should Be from Samples When Judging Additive Color Mixture in Fabric	28
	32

Chapter	Page
Qualifications for a Room Used for	
Judging Samples	33
Type and Number of Judges	33
Setting up Standards of Color and	
Order of Judging	34
The Physics of the Eye When Looking at	
Color Such as Exhibited in the	
Samples of This Study	35
Method of Recording Judges' Opinions	37
Method of Reporting Information of	
a Study Such as This One	38
Expectant Outcome of Color When Mixing	
Colors Additively in Fabric or on the	
Spinning Disk	38
The Effect Texture Has on Color in Fabric	41
III. ESTABLISHING CONTROLS AND PROCEDURES	43
Choosing a Color System to Follow	43
Pre-testing for Samples	44
Controls of the Yarns	47
Controls of Weaves and Sample Size	49
Procedures of Threading the Loom and	
Weaving	50
Controls and Procedures for Judging	52

Chapter	Page
IV. TABLE AND GRAPHIC ANALYSIS OF TWO GROUPS OF	
SAMPLES	60
The Purpose and Content of Tables A, B,	
and C	61
Explanation of Tables	63
Analysis of Complementary Colors in	
Additive Color Mixture	66
Additive Color Mixture in Fabric in Which	
the Warp and Filling Yarns are Two	
Steps Apart on the Munsell Color Wheel	80
V. SUMMARY	97
Samples to be Compared and Method of	
Comparison	97
The Effect of Texture on Additive Color	
Mixture	100
Future Study on This Subject	108
BIBLIOGRAPHY	110
APPENDIX	116

LIST OF TABLES

Table	Page
Series C: Munsell Notations Given Control Samples and Changes in the Textured Samples From the Control Samples	
C-I: Complementary Colors in Additive Color Mixture in Fabric	69
C-II-a: Colors Two Steps Apart on Munsell's Color Wheel in Additive Color Mixture In Fabric	81
C-II-b: Colors Two Steps Apart on Munsell's Color Wheel in Additive Color Mixture in Fabric	82
Series A: Each Judge's Decision as to How the Textured Yarn Samples Changed From the Control Samples in the Same Yarn Colors	
A-I: Red Textured Filling Yarns	119
A-II: Yellow-Red Textured Filling Yarns	120
A-III: Yellow Textured Filling Yarns	121
A-IV: Green-Yellow Textured Filling Yarns	122
A-V: Green Textured Filling Yarns	123
A-VI: Blue-Green Textured Filling Yarns	124
A-VII: Blue Textured Filling Yarns	125
A-VIII: Purple-Blue Textured Filling Yarn	126

Table

Page

A-IX:	Purple Textured Filling Yarn	127
A-X:	Red-Purple Textured Filling Yarn	128
Series B: Munsell Color Notations of the Control		
Yarn Samples and a Summary of the		
Textured Yarn Samples (Series A)		
B-I:	Red Filling Yarn	129
B-II:	Yellow-Red Filling Yarn	130
B-III:	Yellow Filling Yarn	131
B-IV:	Green-Yellow Filling Yarn	132
B-V:	Green Filling Yarn	133
B-VI:	Blue-Green Filling Yarn	134
B-VII:	Blue Filling Yarn	135
B-VIII:	Purple-Blue Filling Yarn	136
B-IX:	Purple Filling Yarn	137
B-X:	Red-Purple Filling Yarn	138

LIST OF FIGURES

Figure		Page
1.	Crewdson's Psychological Color Circle	40
2.	A Comparison of the Hue Favored by Three Different Types of Yarns in Fabric of Additive Color Mixture When Warp and Filling Yarns Were of Complementary Colors	71
3.	Value Graph of Three Types of Yarns in Fabric of Additive Color Mixture When the Warp and Filling Yarns Were of Complementary Colors .	73
4.	Saturation Graph of Three Types of Yarns in Fabric of Additive Color Mixture in Which the Warp and Filling Yarns Were of Complementary Colors	77
5.	A Comparison of the Hue Favored by Three Different Types of Yarns in Fabric of Additive Color Mixture When Warp and Filling Yarns Were Two Color Steps Apart on the Munsell Color Wheel	84
6.	A Value Graph of Three Types of Yarns in Fabric of Additive Color When the Warp and Filling Yarns Were Two Steps Apart From Each Other on the Munsell Color Wheel	88

Figure

Page

7.	Saturation Rating of the Control Samples in Additive Color Mixture When the Warp and Filling Yarns Were Two Steps Apart on the Color Wheel, and the Direction of Change of Samples of the Same Colors When Two Different Textured Yarns Were Added	94
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CHAPTER I

INTRODUCTION

How important is COLOR? Scientists in the past few years have realized the tremendous significance of color. At the close of World War II extensive research was started in the field of color by not only the physiologist, but also the physicist and the psychologist. The study of color has scarcely grown out of its infancy compared with the fuller development of other physical sciences. This backward state of development is evidenced by the scarcity of published material dealing with the subject before 1940.

Because color plays such an important and influential role in today's living, research is being carried forward in many of its phases.

I. COLOR AND ITS FORM

Color results depend on the method in which they are mixed. This led to the popular classification of color mixture phenomena into: additive, applying to the mixtures of colored lights in the eye; and subtractive, applying to the physical mixtures of colored substances. However, this classification is an over simplification as there are many parts to each.

II. THE PROBLEM

The research in this study is concerned with the mixture of two colored yarns in woven fabric. This is called "textile mixture." It occurs when threads of different colors are interwoven and the color viewed from such a distance that the individual threads cannot be distinguished. It is Duncan's theory that the color obtained by mixing colored threads is one approximating an average additive color mixture.¹

This study is essentially concerned with additive color mixture in fabric as it is affected by texture. Texture, in this instance, being two types of slubbed yarns, one type of yarn exhibiting sheen and the other a mat finish. This study is to determine if these two textures, added as filling, affect the appearance of a color by their addition to the control warp yarns as compared to the control filling yarns.

III. THE RELATIONSHIP OF THIS STUDY TO OTHER RELATED STUDIES

This study is in an area of the color field in which, to the best of the investigator's knowledge, there has been no

¹D. R. Duncan, "The Colour of Pigment Mixtures," Journal of the Oil and Colour Chemists Association, XXXII (1949), p. 301.

extensive recorded research or study of this problem. In a few books there was mention of results concerning additive color mixture in fabric. There was no mention, however, of the effect of texture on additive color mixture in fabric. Sheen and mat textured finishes were mentioned by several authors.² In this report the findings of this study will be compared to those found in the review of literature. Through the examination of Titles of Completed Theses in Home Economics and Related Fields in Colleges and Universities of the United States,³ it was found that no research in the field of additive color mixture had been done on either the Master's or Doctor's level of study in the past ten years.

IV. THE SPECIFIC OBJECTIVES OF THIS STUDY

This study of color will limit its investigation to an area relatively unexplored in the science of color. The

²Faber Birren, Functional Color (New York: The Crimson Press, 1939), p. 28; and J. H. Bustanoby, Principles of Color and Color Mixing (New York: McGraw-Hill Book Company, Inc., 1947), p. 23; and W. D. Wright, The Measurement of Color (New York: The Macmillan Company, 1958), p. 22; and Matthew Luckiesh, Color and Colors (New York: D. Van Nostrand Company, Inc., 1938), p. 133; and Hugh R. Davidson, "The Size of Acceptable Color Differences," Optical Society of America, XXXXIII (1953), pp. 581-589.

³Titles of Completed Theses in Home Economics and Related Fields in Colleges and Universities of the United States (Agricultural Research Service - U. S. Department of Agriculture, Washington, D. C., 1957 - 1958).

specific objective of this study are:

1. To compare the differences caused by the use of textured yarns in additive color mixture in fabric.
2. To determine if yarns exhibiting texture create a difference in the appearance of a fabric. To also determine if a mat texture creates a different effect than a sheen texture.
3. To review literature concerning additive color mixture for a basis upon which to make the determinations listed above.
4. To compare samples with each other and with known facts about additive color mixture with regard to hue, value, and saturation. The samples are divided into groups for comparison according to the relationship of the two colors on the color wheel:
 - a. Complementary colors.
 - b. Colors two hue steps apart on the Munsell color wheel.

These two groups, complementary colors, and colors two color steps apart on the Munsell color wheel, were chosen for several reasons. First, in the review of literature data concerning the expectant color of additive color mixture in complementaries was discussed more than any other combinations. Secondly, complementary colors, being opposite on the color

wheel, would make an interesting and contrasting study to colors close together on the color wheel.

The second group of samples chosen, colors two color steps apart on the Munsell color wheel, were picked as a contrast to the complementaries and were thought to be an interesting comparison to them. Colors two steps apart on the wheel were chosen, in preference to analogous colors, for the additive color mixture and the new hue between the two colors was more easily discernible.

V. THE RESEARCH FOR THIS STUDY

The Samples

The research for this study was done on samples specially woven for the study. The yarns were in part commercially dyed yarns and in part laboratory dyed to resemble, as closely as possible, the ten basic colors of the Munsell color wheel at their most saturated level. The samples were woven with specific controls established through pretesting to determine the size of thread, the size of sample, the type of weave, and the type of textured yarns to be used.

The Judging

The samples were judged macroscopically by three qualified

judges⁴ under conditions established in the review of literature.⁵ The control samples were given Munsell color notations. The textured samples of sheen and non-sheen textured yarns were compared to the control sample with regard to change in hue, value and saturation.

The Review of Literature

The information recorded from the judging of the samples was compared to the data found in the review of literature. Since the study of color is being explored in the many different fields of fine arts, psychology, engineering,

⁴The qualifications of the three judges are given in the appendix.

⁵Faber Birren, Monument to Color (New York: McFarlane Warde McFarlane, 1938), p. 23; and Olsen B. Buchmann, "The Objective Measurement of Colour and Colour Changes," Transactions of the Danish Academy of Technical Science (Contributions from the Danish Institute for Textile Research, No. 11. Kobenhavn, Denmark, 1950), p. 14; and J. H. Bustanoby, Principles of Color and Color Mixing (McGraw-Hill Book Company, Inc., New York: 1947), p. 22; and Frederick M. Crewdson, Color in Decoration and Design (Wilmette, Illinois: Frederic J. Drake and Company, 1953), p. 63; and Ralph Evans, An Introduction to Color (New York: John Wiley Inc., 1948), p. 63; and "How Does Light Affect Color?", Architectural Forum, XC (January, 1949), pp. 115-118; and Richard S. Hunter, "Photo-electric Color Difference Meter," Journal of the Optical Society of America, XLVIII (American Institute of Physics, Number 12, December, 1958), p. 985; and Luckiesh, op. cit., p. 133; and Walter Sargent, The Enjoyment and Use of Colors (New York: Charles Scribner's Sons, 1923), pp. 78-80; and William Watson, Textile Design and Colour (New York: Elementary Weavers and Figured Fabric; Longmans Green and Company, 1937), p. 139; and Wright, op. cit., p. 62.

chemistry, architecture and physics, each phase overlapping, yet holding an express purpose of its own, it was necessary to check the sources in each of these phases.

The review of literature for this study was done at eight of the Columbia University libraries, New York Public Library, New York's Chemistry Club Library, Teachers College Columbia, the library at Michigan State University and the Public Library of Indianapolis, Indiana.

VI. THE VALUE OF THIS RESEARCH

The primary value of this study is to contribute additional knowledge to the field of research in additive color mixture in fabric. It is also the investigator's hope that the study will encourage new use of additive color mixture and texture in fabric by helping the designer pre-determine results or effects he can expect to obtain in fabric when combining certain designated colors and/or types of textured yarns.

CHAPTER II

REVIEW OF THE LITERATURE

Extensive research in color science was started fifteen years ago. There were relatively few books dealing with the subject before 1940. This situation was particularly true concerning the subject of additive color mixture in fabric. There have not been any books dealing with the effect of texture on additive color mixture in fabric, - the problem with which this study is concerned.

I. WELL-KNOWN COLOR SCIENTISTS

All through the ages artists and scientists have been working with the same phenomena: light and vision. The discoveries of the artists were generally recorded in their paintings, and scientists were continually making new experiments and recording them.¹ Ostwald and Munsell were two outstanding figures in the field of color research. Ostwald's system is widespread throughout Europe. The Munsell system is one of the most widely accepted systems of color identification in the United States.²

¹Egbert Jacobson, Basic Color (Chicago: Paul Theobald, 1948), p. 4.

²Faber Birren, New Horizons in Color (New York: Reinhold Publishing Corporation, 1955), p. 192.

Albert Munsell

Albert Munsell was particularly outstanding in the field of color standardization. He designed a color solid in the form of a sphere in which the physical, physiological and psychological aspects of color were clearly organized. He also made use of symbols to replace confusing nomenclature.³

In the Munsell system every color sensation is united by three distinct qualities. They are defined as hue, value, and chroma.⁴ Hue is the name of the color, and holds the direction around the Munsell color sphere. Value, the amount of lightness and darkness in a color, is designated on the sphere by the vertical direction; lightness being at the top, and darkness, the bottom. Chroma is the dullness or brightness of the color. It is used to express the quality of saturation. It is designated on the sphere from the center out to the edge on a horizontal plane.

Five principle hues were chosen by Munsell, not because they had any particular significance, but because he

³Frederic Crewdson, Color in Decoration and Design (Wilmette, Illinois: Frederick J. Drake and Company, 1953), p. 94.

⁴The word chroma is used by Munsell. However, more recently the word saturation has become more accepted in the I.S.C.C. standardization of color language. In this study the term saturation shall be used except when referring to Munsell when the term chroma will be used.

believed that they were visually equidistant in hue from each other.⁵ The five hues are: red, yellow, green, blue and purple. Because Munsell decided to use a decimal system, the five principle hues were subdivided so that between them were five intermediate hues: yellow-red, green-yellow, blue-green, purple-blue and red-purple.

The Munsell system has compiled its theory into a convenient and easy to use book containing about four hundred samples accurately prepared. Each color, identified by its rational nomenclature, is easily designated.

Evans, a noted colorist, explained why the Munsell notations covered only a limited region:

The limitation is not due to a failure on the part of the dye makers to secure a full range of colors. It is inherent in the nature of the dyes themselves in that, for any dye of a particular hue and saturation, there is an upper limit to the reflectance that it can have if it is illuminated by a light source of broad and continuous radiant energy distribution.⁶

Ostwald Color Theory

The Ostwald theory of color is similar to Munsell's in many ways. He, like Munsell, describes a color in terms of its hue, and value; white content and black content.

⁵Crewdson, op. cit., p. 84.

⁶Ralph M. Evans, An Introduction to Color (New York: John Wiley and Sons, Inc., 1948), p. 286.

Saturation, however, is not stressed nearly as greatly as in the Munsell system. "Some surface colors, mainly those of high purity, have not been included in the Ostwald system."⁷

The Ostwald system arranges the colors in the form of a double cone. The axis of the cone is composed of eight gradations from black to white. The equator consists of twenty-four full colors developed from four basic complementaries: blue, yellow, red and green. Twenty-four equilateral triangles (one for each full color) round out the wheel. They are formed by eight steps up from full color to white; clear light colors, and eight steps down from full color to black; clear dark colors. Each triangle is occupied in the middle by intermediary "shadow" steps; a mixture of full color with both black and white.⁸

The colors in the Ostwald system are more scientifically mixed to fit into his perfect double cone, whereas in the Munsell system, the characteristic of the color dictates the shape of the sphere.

⁷Olsen B. Buchmann, "The Objective Measurement of Colour and Colour Changes," Transactions of the Danish Academy of Technical Science, No. 4, Contributions from the Danish Institute for Textile Research, No. 11, (Kobenhavn, Denmark: 1950), p. 25.

⁸"Basic Color," Architectural Forum, XC (April, 1949), p. 224.

II. TYPES OF COLOR MIXTURE

Color results depend on the form in which color is mixed. Pigment, light, and vision are the three methods in which color can be mixed, each method producing a different result.

Pigment Mixture

Pigment mixture is called subtractive color mixture. When pigments are mixed, the result is always downward. Each of the pigments in the mixture absorbs something from the light which falls upon it. The result is a color which has less brightness than any of the components alone, hence the term subtractive. For example, when yellow and blue pigments are mixed in equal amounts, a green hue results which is less bright than either the yellow or blue.⁹

Colored Light Mixture

The mixture of light is called additive color mixture. It always works upward, each component adding to the other's brightness. The intensity of the new color contains the total energy of the two colors that were mixed. For example, in

⁹Frederick M. Crewdson, Color in Decoration and Design (Wilmette, Illinois: Frederick J. Drake and Company, 1953), p. 64.

combining red and green lights the result is yellow, and the intensity of this yellow is equal to the total energy of red and green.¹⁰

Mixing Colors Visually

Mixing colors visually was the method of mixture in which this study was mainly interested, for it includes the mixture of colored yarns. The mixture of colored yarns was classed by many scientists as additive and by others as medial color mixture.

The blending of two colors by a revolving disk was generally the demonstration scientists used to illustrate the visual mixture. The results of the disk were the same as the mixing of colored fibers and yarns.¹¹

III. DOES THE TERM "ADDITIVE" APPLY TO THE MIXING OF DIFFERENT COLORED YARNS?

Due to the lack of standardization of the color language until just recently, it was found in the review of literature that disagreement was frequent among authors as to the terminology. The term "additive color mixture," as applied to the mixing of colored yarns, was one of these

¹⁰Ibid., p. 69.

¹¹Ibid., p. 68.

terms about which there was disagreement. The following is a review of the various authors' points of view concerning the term "additive color mixture."

Authors who have not approved of the term "additive"

Birren. Faber Birren, in Functional Color, pointed out that color mixture by vision was neither subtractive nor additive. He said that "they are medial and the resultant colors are always a compromise between the value of the two colors employed in the mixture."¹²

Crowdson. In his book Color in Decoration and Design, Crowdson also used the term medial. He felt that scientists who call visual color mixture additive, liken the mixture to the blending of colored lights. "This is erroneous," Crowdson said.¹³

Duncan. The author Duncan stated that the term additive was an over-simplification and that the theory of medial mixture was really a subdivision under the name additive.¹⁴

¹²Faber Birren, Functional Color (New York: The Crimson Press, 1939), p. 71.

¹³Crowdson, op. cit., p. 69.

¹⁴D. R. Duncan, "The Color of Pigment Mixture," Journal of the Oil and Color Chemists' Association, XXXIII (July, 1949), p. 297.

In continuing to read and evaluate the different theories, Duncan appeared to be more correct than the others. By close evaluation of the theories of colored yarn mixture in fabric, the results of the theories seemed to be the same in spite of the name given to them.

Crewdson's statement on complementary colors. The following was an experiment given by Crewdson establishing facts of medial color mixture.

Crewdson mixed equal parts of complements yellow and blue on a spinning disk. He achieved gray. The same result was obtained by mixing complements red and green. He then stated; "When complementary colors are medially mixed in proper amounts, the result is always neutral gray."¹⁵

Authors in Agreement of Using the term "Additive."

Egbert Jacobson. Egbert Jacobson, one of the scientists who used the term "additive" for visual color mixture, pronounced essentially the same statement as Crewdson. In Jacobson's book Basic Color, he pointed out that the basic requirements of complementaries was that two colors spin to neutral gray on a spinning disk.¹⁶

¹⁵Crewdson, op. cit., p. 69.

¹⁶Egbert Jacobson, Basic Color (Chicago: Paul Theobald, 1948), p. 14.

As Jacobson continued, he pointed out the reason for the term "additive." He cited the mixture of complementaries blue and yellow on a spinning disk. He said the color of complementary mixtures was a result of light reflected from the rapidly alternating disk, a mixture of lights, not pigments. He said the eye received a mixture of blue and yellow light. This light so acted on the receptors in the eye as to produce the sensation of gray in the brain.¹⁷

Ralph Evans. Mr. Ralph Evans stated that additive mixture was a common phenomenon in textile materials in which threads of various colors were woven into a fabric.

When the light of the two different energy distributions reaches the eye, they are received as though they are a single light distribution which may be calculated by adding the two together. Such a combination of light of two or more qualities is known as an additive mixture.¹⁸

Seibert Duntley. Duntley, from a color standpoint, felt that the blending of fibers could be considered an optical problem. He explained in his book Colored Fiber Blends that:

Almost the entire reflectance of the blend is obtained from the surface fibers lying near the top of the mass. Since the individual fibers are too small to be seen by the eye under normal inspection, the observed color is an additive mixture of the

¹⁷ Ibid., pp. 15-16.

¹⁸ Ralph M. Evans, An Introduction to Color (New York: John Wiley and Sons, Inc., 1948), p. 63.

light reflected by each of the constituent colored fibers.¹⁹

W. D. Wright. Wright, in his book The Measurement of Color, reported essentially the same information. He stated that by the mixing of color in the retina of the eye, i.e.,--when two spectral components were ultimately combined and focused on the retina of the eye,--they were additively mixed.²⁰

Duncan. Duncan pointed out, as did the aforementioned authors, that colored thread mixture in fabric was one of many forms of additive color mixture.²¹

In spite of the difference in the various authors' interpretations and applications of the term "additive," it has been shown that basically the authors agree on the results attained from colors mixed on the revolving disk.

There appeared to be a greater number of authorities who gave cogent reasons for the use of the term "additive color mixture" as applied to the mixture of colored yarns. These authorities also discussed and named many other

¹⁹Seibert Q. Duntley, "Colored Fiber Blends," American Dyestuff Reporter, XXX (September 8, 1941), p. 698.

²⁰W. D. Wright, The Measurement of Color (New York: The Macmillan Company, 1958), p. 62.

²¹Duncan, op. cit., pp. 297-301.

additive color mixtures that attained results similar to the mixing of colored yarns.²²

IV. THE LUSTER AND TEXTURE OF YARNS

Luster and texture have a marked influence on the appearance of yarns and fabric.

²²Crewdson, op. cit., p. 68. In each of the following cases, the mixtures produce the same results as when colors were mixed on the revolving disk: (1) when different colored threads were woven or interlaced together; (2) when fine lines, dots, etc., of one color were distributed over a ground of another color; and (3) when opaque colored powders were mixed.

Mathew Luckiesh, Color and Colors (New York: D. Van Norstrand Company, Inc., 1938), p. 144. Luckiesh described the following as being included in types of additive color mixture: (1) the blending of differently colored fibers and yarns; (2) differently colored threads twisted together and (3) by combining (either as fiber mixture or a twist) two materials in the undyed state which had different affinities for coloring matter; i.e., wool and cotton then submitting the woven cloth to two dyeing operations (cross-dyeing).

Duncan, op. cit., pp. 297-301. Duncan gave a detailed breakdown of areas included in additive color mixture. Textile mixture was one area he included. To mention some that have not yet been cited: (1) mosaic pattern composed of patches of different color viewed at a distance; (2) a revolving disk with different colored sectors; (3) flashes of light of different colors following one another in rapid succession.

Evans, op. cit., p. 63. Evans stated: "Additive mixing is a common phenomenon in textile materials in which threads of various colors are woven into some sort of pattern."

Luster and Sheen

Luster in a yarn is dependent upon both the physical structure of the fiber and the yarn itself. Surface irregularities, whenever they may occur, tend to diminish the degree of luster. The straighter the fiber and the greater the degree of parallelism, the greater is the amount of luster. A unicellular fiber such as rayon is perfectly smooth, hence has great luster and high light reflectancy.²³

Yarns with sheen. Faber Birren felt that luster such as the eye sees in silk or rayon appeared to lie on, or above, a surface and not to belong to the color of the surface itself. He felt that the surface seemed to carry the luster.²⁴

Yarns without sheen. A fiber with a down surface, such as cotton that has been roughly carded and the fibers intermingle and cross each other in their natural condition, produces very little luster. Hence, in dyed colors it is lacking in brightness. If a cotton has been finely combed

²³ J. H. Bustanoby, Principles of Color and Color Mixing (New York: McGraw-Hill Book Company, Inc., 1947), p. 23.

William Watson, Textile Design and Colour (New York: Longmans Green and Company, 1937), p. 142.

²⁴ Faber Birren, Functional Color, (New York: The Crimson Press, 1939), p. 28.

and the fibers have been paralleled, the yarns have a slight luster.²⁵

Texture

Bustanoby stated that when dealing with textures such as a rough or pebbly surface, or one that was smooth or with a gloss, it was very difficult to match them. One of the most frequent problems in color matching was caused by the differences in texture. Different types of materials, such as cotton, silk, wool and rayon, even when they were dyed with identical color, appeared quite different from one another. This was because of their respective textures, refractive indexes, and color absorbent qualities.²⁶

Hugh R. Davidson, in his article "The Size of Acceptable Color Differences," explained that it was nearly impossible to match the exact colors in two fabrics made of different textures or fibers.²⁷

V. HOW WEAVES AFFECT SAMPLES

The Plain Weave

The plain weave was the simplest form of interlacing

²⁵Watson, op. cit., p. 142.

²⁶Bustanoby, op. cit., p. 23.

²⁷High R. Davidson, "The Size of Acceptable Color Differences," Optical Society of America, XLIII (American Institute of Physics, July, 1943), pp. 581-589.

yarns in an alternate order. This weave exhibited the least amount of pattern in a fabric. With the least amount of pattern, the color combinations can be most easily observed.

The Twill Weave

The Twill order of interlacing causes diagonal lines to be formed in the cloth. The points of intersection moved one thread outward and one upward on each succeeding pick. The direction of the diagonals can run either way.²⁸ This diagonal line gives the samples a simple pattern which tends to slightly change the appearance of the fabric from that of the plain weave.

VI. CHOOSING BETWEEN THE MECHANICAL OR HUMAN EYE

METHOD OF JUDGING SAMPLES

There were many different ways in which the samples of this study could have been judged. The method of judging and controls for judging the samples were determined as a result of the review of literature.

The first basic decision was whether the samples should be judged by a scientific mechanical system or visually by

²⁸Watson, op. cit., p. 142.

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the human eye.

Scientific and Mechanical Methods for Judging.

Scientific methods for testing and judging additive color mixture were found to be such complex instruments as the colorimeter, tristimulus reflectometer and the spectrophotometer.

Within the past two decades the science of colorimetry has experienced a great technological development.²⁹

Colorimetry is the technique of the measurement of color; it is only a part of the science of color, but more particularly of physics and psychology Colorimetry is based on the idea that a relationship can be found between physical specifications of color stimuli and the sense perception that arises from them.³⁰

The language of colorimetry has been improved, and has been agreed upon internationally. "Both the illuminants and the characteristics of a normal human eye have been standardized by the International Commission on Illumination and ratified by twenty-six nations."³¹

²⁹Siebert Q. Duntley, "Colored Fiber Blends," for Northern New England Section of American Association Textile Chemical and Color. American Dyestuff Reporter, XXX (September 8, 1941), p. 699.

³⁰Optical Society of America. The Science of Color (Binghamton, New York: Vail-Ballou Press, Incorporated, 1953), p. 40.

³¹Duntley, loc. cit.

The Colorimeter. One use of the colorimeter was to derive the three tristimulus values X Y Z which specify the amount of defined red, green and blue stimuli which, when mixed additively, match the color under test.³²

Tristimulus Reflectometer. In 1958 a tristimulus reflectometer was being developed to measure color of surfaces on scales given approximately the spacing of the Munsell color system. It was expected to have "precision equal to or better than that of the eye differences." Usually a tristimulus reflectometer detects luminous reflectance with a precision which is considerably better than the eye's ability to see the same difference.³³

However, the normal eye is more sensitive to chromatic (horizontal) than to luminous differences in color. Conversely, the tristimulus reflectometer is less sensitive to chromatic than luminous differences.³⁴

A tristimulus color match is not generally observed visually and, therefore, the British feel that this is a weakness in the system.³⁵ This pointed out the importance

³²W. D. Wright, Dr. "J. S. Color Science Speeds Up," Modern Textile Magazine, XXXIII (December, 1952), p. 34.

³³Richard S. Hunter, "Photoelectric Color Difference Meter," Journal of the Optical Society of America, XXXXVII, Number 12 (December, 1958), p. 985.

³⁴Ibid.

³⁵Wright, op. cit., p. 31.

scientists place on the eye's ability and accuracy in judging color.

Spectrophotometer. The spectrophotometer is necessary for the proper measurement of the reflectance value in testing fiber blends.³⁶ However, the data may be used in chemical analysis, in controlling and checking the quality of raw materials and in calculating dye mixtures.³⁷

The C.I.E. The C.I.E.³⁸ is the only system to include every form of chromatic phenomena. However, the following reason is given for not using this system in this study.

Buchmann reports that:

. . . in some respects it is intrinsically so abstract as to strongly impede its practical application. Furthermore, instrumental difficulties play an important part, and the measurements require considerable time. These are all factors contributing to the restricted application of the system.³⁹

All of these complex mechanical machines appeared to be more technical than necessary for this study. Because of this and also because "photoelectric color machines have not

³⁶Duntley, op. cit., p. 689.

³⁷Wright, op. cit., p. 33.

³⁸Buchmann, op. cit., p. 29. The accepted abbreviation for the International Colorimetric System adopted by the International Commission on Illumination in 1931.

³⁹Ibid.

been completely perfected as yet,"⁴⁰ mechanical judging was not strongly advisable.

The Human Eye and Attitude in Judging

In the review of literature and through a personal interview with a color researcher, it was found that a great deal of importance was placed on the eye and attitude of human beings.

Faber Birren. Faber Birren, a noted color scientist, felt strongly that "the human attitude must always prevail in judging color. Color must be applied as it looks . . . rather than to exist apart from life."⁴¹ Nearly every experience one has with color involves human and psychological factors -- human experience as a sensation. Functional color, especially in its visual and emotional aspects as is the case with fabrics for interior design, is strongly psychological.⁴²

Daniel Smith. Mr. Daniel Smith at the International Color Association in New York City personally studied the samples for this research. In spite of all the mechanical color equipment he worked with and used for his research each day, he highly recommended that the judging of the samples

⁴⁰ Hunter, loc. cit.

⁴¹ Faber Birren, Functional Color (New York: The Crimson Press, 1939), p. 14.

⁴² Ibid., p. 13.

for this research should be done by human eye. He stated that many valuable color research judgments have been and are still being judged by the human eye. He then emphasized the importance still placed on eye judging in co-ordination with mechanical judging.

Mr. Smith continued by pointing out that if the purpose of this research was to be applied to interior design and fabrics, it essentially then dealt with what the eye saw, and should, therefore, be judged in the same manner.⁴³

VII. CITING ACADEMICALLY ACCEPTED COLOR JUDGING

DONE BY THE HUMAN EYE

Danish Experiment

Buchmann, in his article, "The Objective Measurement of Colour and Colour Changes," reported a Danish experimental laboratory's use of judging by eye. In one problem, change in fabric color through washing was judged by stating: unchanged; slightly changed, or markedly changed.⁴⁴

⁴³Mr. Daniel Smith, color researcher, Interchemical Corporation Color Center, 432 West 45th Street, New York, New York. Interview.

⁴⁴Olsen B. Buchmann, "The Objective Measurement of Colour and Colour Changes," Transactions of the Danish Academy of Technical Science, No. 4 (Kobenhavn, Denmark, 1950), p. 12.

Experiment on the Aesthetics of Light and Color

Emma Baker, in her report on "Experiments on the Aesthetics of Light and Color," recorded an experiment judged by the eye. In this experiment the judges had an apparatus which showed a ground color and then showed another color on top of the ground color by means of light through a gelatin. As one color was shown at different proportions to the other, twenty-five people compared the color combinations by the terms; very pleasant, pleasant, indifferent or unpleasant. All twelve colors were done in this way. Some of the twenty-five people did the whole series and some did half or more or less.⁴⁵

The Opinion of Wright

Wright, in an article in Modern Textile Magazine, explained that visual judging of color by the trained eye seemed to be very accurate and much value was placed on it.⁴⁶

Webber, Bellmeyer and Brown Recorded Eye Judging

Webber told how self-judging was used for judging certain tests and experiments on color.⁴⁷ Brown also related

⁴⁵ Emma S. Baker, "Experiments on the Aesthetics of Light and Colour" (Vol. II of University of Toronto Studies, ed. A. Kirschman, Toronto: Librarian of the University of Toronto, 1907), pp. 25-32.

⁴⁶ Wright, op. cit., p. 34.

⁴⁷ A. C. Webber and F. W. Bellmeyer, Jr., "Three-Dimensional Color Models Constructed on the CIE and Munsell System," Journal of the Optical Society of America, Vol. XLIII, No. 2 (February, 1957), pp. 137-143.

similar tests. Some tests such as color discrimination were done partially by personal judgment of a group of chosen people.⁴⁸

VII. THE INFLUENCE OF ILLUMINATION IN JUDGING

"Color has its source, in it is the property of light that reaches the eye. Without light there is no color."⁴⁹ Therefore, the type of illumination on the samples while being judged was of great importance.

Degree of Illumination in Judging Color

The color appearance of an object under one illumination, can be different from its appearance under another degree of illumination. Under these varying degrees of illumination, colors appear to change in hue as well as value and saturation.⁵⁰

It is an accepted theory that most colored surfaces owe their hue to the fact that they absorb part of the spectrum

⁴⁸W. R. Brown, "Color Discrimination of Twelve Observers," Journal of the Optical Society of America, Vol. XLIII, No. 2 (February, 1953), pp. 69, 70.

⁴⁹Frederick M. Crewdson, Color in Decoration and Design (Wilmette, Illinois: Frederick Drake and Company, 1953), p. 63.

⁵⁰Walter Sargent, The Enjoyment and Use of Color (New York: Charles Scribner's Sons, 1923), p. 80; and R. W. Burnham, R. M. Evans and S. M. Newhall, "Prediction of Color Appearance with Different Adaption Illuminations," Journal of the Optical Society of America, XLVII, No. 1 (January, 1957), p. 41.

a.

b.

c.

d.

e.

f.

and reflect the remainder. Faber Birren explains:

The way in which we see the color of a surface is in large measure dependent of the intensity and wave-length of the light it reflects, and at the same time definitely dependent upon the nature and intensity of the illumination in which it appears.⁵¹

Walter Sargent, in his book The Enjoyment and Use of Color, explains that:

In a moderately bright light these surfaces are able to swallow up the larger proportion of those rays which come within the range of their power of selective absorption. Consequently, the rays which they do reflect, and which give them their color, are fairly pure and unaffected by those of other wave-lengths. When the illumination becomes intense, the deluge of light overtakes, and it can no longer take up all the rays of any single color. The flood of light is therefore largely reflected, and our eyes receive from the object, not only the rays characteristic of its color but also a large number of all the other hues of the spectrum. If the color of the object is red, that hue is still likely to predominate, but it will be accompanied by so many other rays that the purity of the color will be lessened. The surface will be more brilliant because it reflects a greater amount of light than in low illumination, but any one particular color will be less pure because it is submerged in the white light.⁵²

Sargent also stated that in strong light each color tended to appear more yellowish. In shadow, he reported that each color appeared to take on the suggestion of violet.⁵³

⁵¹Faber Birren, Monument to Color (New York: McFarlane Warde McFarlane, 1938), p. 23.

⁵²Sargent, op. cit., p. 78, 79.

⁵³Ibid., p. 80.

Tone of the Illumination

Light has color and, therefore, different tones of light reflected on the samples will give them a different character. Burnham stated in his article "Predictions in Color," that the tone of the light will change the hue, value and saturation of the color under examination.⁵⁴

Best Light to Use for Judging

Crewdson's suggestion. Crewdson felt that bright daylight was the kind of light most satisfactory for mixing and matching colors. He pointed out that it was necessary to avoid both direct and reflected sunlight, especially when the reflection came from a neighboring colored surface. He felt that a steady north light on a bright day was the ideal condition. However, he stated, that diffused, color - corrected artificial light, when it stimulated daylight as closely as possible, was very good.⁵⁵

Birren's suggestion. Since different amounts of light changed the effect of color, Faber Birren emphasized the importance of using a standard setup of controlled daylight for problems of judging, in order to obtain a true comparison.⁵⁶

⁵⁴Burnham, loc. cit.

⁵⁵Crewdson, op. cit., p. 76.

⁵⁶Faber Birren, Functional Color (New York: The Crimson Press, 1939), p. 39.

Hunter's suggestion. Hunter stated that for experiments of judging color, normal daylight should be used for observing conditions.⁵⁷

Artificial Source Nearest to Standard Daylight

The artificial source nearest to standard daylight, as set up by the International Color Council, is the fluorescent with a temperature 6,500°K.⁵⁸

Other Requirements for Effective Lighting

Faber Birren pointed out many more requirements for effective lighting. He stated that not only does the illumination need to be controlled and constant for all samples, but that the illumination should be well distributed and approximately the same strength at every point, and in almost every plane in space. It was important that the eyes of the judges should not be blinded by the light source or by the reflection from illuminated objects. The colors of the samples should be clearly visible and the illumination should

⁵⁷Richard S. Hunter, "Photoelectric Color Difference Meter," Journal of the Optical Society of America, XLVIII, No. 12, (December, 1958), p. 985.

⁵⁸A temperature scale set up in degrees Kelvin is used as a basic measurement. Zero, on the Kelvin scale, is at minus 523.4 F. No heat exists at this temperature. (6,500 K equals noonday - mid altitude). "How Does Light Affect Color?", Architectural Forum XC (January, 1949), pp. 115-118.

be stable.⁵⁹

"Bad lighting exists where adaptive changes constantly take place and particularly where light sources are exposed."⁶⁰

IX. DISTANCE JUDGES SHOULD BE FROM SAMPLES WHEN
JUDGING ADDITIVE COLOR MIXTURE IN FABRIC

Evans

Evans, in his book An Introduction to Color, pointed out the method of obtaining the proper distance for judging the additive mixing of threads in a textile material in which threads of various colors were woven into some sort of pattern. He explained that from a short distance the individual threads may be visible, but at a certain distance these become invisible with the pattern still showing. Still further away, he explained that the pattern disappeared. At this distance the eye blended the color into a true additive color mixture.⁶¹

Smith

Mr. Daniel Smith at the Interchemical Color Center in New York, studied the samples of this report and observed

⁵⁹Birren, op. cit., pp. 43, 45.

⁶⁰Ibid.

⁶¹Ralph M. Evans, An Introduction to Color (New York: John Wiley and Sons, Inc., 1948), p. 86.

D. R. Duncan, "The Colour of Pigment Mixtures," Journal of the Oil and Colour Chemists Association, XXXII (149), p. 301.

them from various distances. He suggested fifteen feet as being a distance at which he felt the color of the yarns mixed additively in the eye.⁶²

X. QUALIFICATIONS FOR A ROOM USED FOR JUDGING SAMPLES

Most of the specifications for the room pertain to lighting and were discussed under the heading of "Illumination."⁶³ The room should have controlled even lighting conditions. Also, it was important that the color of the walls should not be one that would reflect a hue influencing the color of the samples.

It was also necessary that the room be long enough to enable the judges to view the samples at a proper distance in order to obtain an additive color mixture.

XI. TYPE AND NUMBER OF JUDGES

The judgments of color by the human eye cited earlier,⁶⁴

⁶²Mr. Daniel Smith, color researcher, Interchemical Corporation, Color Center Laboratory, 432 West 45th Street, New York City.

⁶³Discussion of illumination, Chapter II, pp. 28-33.

⁶⁴Judgments of color by the human eye cited earlier in Chapter II, Section VII, pp. 26, 28.

recorded judges numbering from one to twenty-five persons. Some of these judges were trained in color judging and had had much experience with color, and others had no color judging experience. In the case of few judges, such as one or two, a color scientist or persons with experience in the color field were used.

XII. SETTING UP STANDARDS OF COLOR AND ORDER OF JUDGING

Buchmann stated that it was necessary to set up a standard color and then compare the samples to it.⁶⁵

Faber Birren established an order and method of judging samples using the Munsell notation system. (1) First, the color should be determined. (2) Second, the value (corresponding to a neutral gray) should be established. (3) Third, the saturation or purity of the color should be determined.

Thus: R 5/6 signified Red (Munsell) at a five level of value, and six steps removed in saturation from the neutral gray scale.⁶⁶

⁶⁵Olsen B. Buchmann, "The Objective Measurement of Colour and Colour Changes," Transactions of the Danish Academy of Technical Science (No. 4, Contributions from the Danish Institute for Textile Research, No. 11, Kobenhavn, Denmark: 1950), p. 14.

⁶⁶Faber Birren, Color Dimensions (Chicago: The Crimson Press, 1934), p. 7.

XIII. THE PHYSICS OF THE EYE WHEN LOOKING AT COLOR SUCH AS EXHIBITED IN THE SAMPLES OF THIS STUDY

Mixing the Colors in the Eye

When the light from two different energy distributions (colored yarns) is focused on the retina of the eye, it is combined additively. It is received as though it was a single light distribution which may be calculated by adding the two colors together.⁶⁷

The Effect of the Juxtaposition of Color on the Eye

When colors were in juxtaposition to each other, they appeared different to the eye. Each hue seemed to influence the hue of its neighbor, since each appeared to be tinged with the complementary hue of its neighbor. Thus, in a cloth consisting of red and blue stripes, the red appeared tinged with yellow -- the complementary of blue, and the blue with bluish-green -- the complementary of red.⁶⁸

The Effect of Eye Strain and Fatigue of the Color Nerves

Many sources caution to guard against eye strain and

⁶⁷Evans, op. cit., p. 64; and W. D. Wright, The Measurement of Color (New York: The Macmillan Company, 1958), p. 62.

⁶⁸William Watson, Textile Design and Colour, Elementary Weaves and Figured Fabric (New York: Longmans Green and Company, 1937), p. 133.

fatigue. It is easy to abuse the eyes unconsciously in precise color work. Eye strain will also cause the eyes not to see color as it actually is.

Exhaustion of the color nerve can cause a color to appear duller when looked at for some time. The appearance of a color is affected when viewed immediately after another color.⁶⁹

The exact relationship between color and the eye is still in its theoretical phase. The Young-Helmoltz theory states:

The retina has three groups of nerve fibers. One of these groups is sensitive to the red wave lengths, the second to the green waves, and the third is to the blue waves. When a color is looked at, the corresponding nerves are resting. When the eye is transferred to another surface, the rested nerves produce sympathetically an after-image which is complementary in color to the first color. Thus by looking at red, the nerves that are sensitive to red become fatigued while the green and blue groups of nerves are resting. If a white surface (which excites the red, green and blue groups equally) is then looked upon, the red nerves are too exhausted to respond, whereas the green and blue groups act together, so that a bluish-green after-image appears.⁷⁰

Methods to Prevent Eye Strain When Judging Color

Bustanoby, in his book Principles of Color Mixing, suggested that, to avoid eye strain while working with color,

⁶⁹ Ibid., p. 139.

⁷⁰ Watson, op. cit., p. 133.

it was helpful to blink the eyes naturally and to avoid staring. Between color matching periods it was necessary that the eyes be rested for a short period by changing the focus to some distant object and then closing the eyes momentarily.⁷¹

To avoid color judging defects from tired eyes, Watson recommended passing the eyes from one color to another. It would be helpful to transfer the eyes at intervals from the color of the cloth to its complementary color. For instance, turning the eyes from red to green or an olive color would help.⁷²

XIV. METHOD OF RECORDING JUDGES' OPINIONS

Only two different color judgments found in the review of literature remarked on the method by which the judges judged the samples.

Danish Experiment

In the Danish Experiment⁷³ the judges stated that the samples under study appeared: unchanged, slightly changed, or markedly changed. They also pointed out that it was impossible

⁷¹J. H. Bustancby, Principles of Color and Color Mixing (New York: McGraw-Hill Book Company, Inc., 1947), p. 22.

⁷²Watson, loc. cit.

⁷³Buchmann, op. cit., p. 5-145.

to state whether a red and blue fabric had the same characteristics of fastness or not.

Emma Baker Report

In the Emma Baker report⁷⁴ of the judging of samples by eye, the twenty-five judges compared the color combinations being judged and stated: very pleasant, pleasant, indifferent or unpleasantness of the combinations.

XV. METHOD OF REPORTING INFORMATION OF A STUDY SUCH AS THIS ONE

Most of the information reported on judging was simply in narrative form. Emma Baker's report was the only one in which graphs and charts were exhibited to help explain data found in the study.⁷⁵

XVI. EXPECTANT OUTCOME OF COLOR WHEN MIXING COLORS ADDITIVELY IN FABRIC OR ON THE SPINNING DISK

There was not a great deal of information given by the various authors as to the colors that could be expected

⁷⁴Baker, op. cit., p. 25.

⁷⁵Ibid., pp. 28-32.

by the additive mixing of colors on a revolving disk or in fabric.

Jacob's Theory of Determining the Resultant Color

Jacobs felt that by knowing the colors being mixed, and the amount of each, the resulting color could be determined. Jacobs mentioned that if two colors were used in a weave "we will have many more than just double the number of shades."⁷⁶ He explained, for example, that combining colored yarns "crimson and yellow would give crimson, red and yellow and all shades in between," depending on the amount of color each yarn has on the surface.⁷⁷

Crewdson's Explanation of Calculating the Expectant Color

Crewdson had stated a detailed and very clear explanation of his theory of the expectant color in additive color mixture. The details of his theory and his diagram were included to facilitate understanding of his theory. Crewdson's theory is similar to that of Jacobs' and other color scientists'. Figure 1 shows an arrangement of the eight principle hues of the psychological color circle.

⁷⁶ Michel Jacobs, The Art of Color (New York: Doubleday Page and Co., 1923), p. 51.

⁷⁷ Ibid.

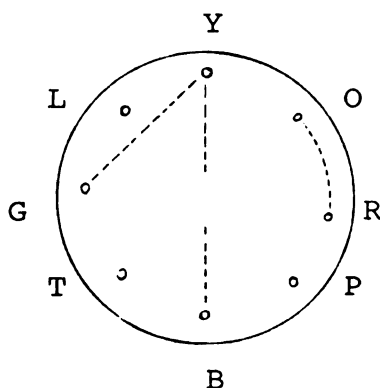


FIGURE 1.

CREWDSON'S PSYCHOLOGICAL COLOR CIRCLE⁷⁸

In the center is neutral mid-gray. All hues produced by mixing on the revolving disc different proportions of any two colors, lie on a straight line joining the colors concerned. For example, the hues that result from the mixing of varying proportions of yellow and green lie on the line Y-G. They will vary from yellow through leaf to green according to their position on the line.

The colors mixed in this manner lose very little of their original brightness because the saturated hues are at middle brightness the same as the mid-gray at the center. However, their saturation or purity is affected and depends upon how far the resulting mixtures are from the circumference of the circle. The point located at the middle of the line Y-G represents a mixture of equal amounts of yellow and green. It is the least pure color resulting when these two colors are medially mixed, because it is the nearest point to the mid-gray center and so contains most gray.

Now suppose we mix red and orange. The resulting colors will lie on the line R-O, and because none of them are far removed from the circumference of the circle, they are almost pure.

⁷⁸Crewdson, op. cit., p. 67, Figure 4, Plate 3.

On the other hand, when colors yellow and blue are mixed in varying proportions, some of the colors obtained are very close to the mid-gray center, of them, namely that resulting from mixing equal parts of yellow and blue, actually lies at the center of the circle and therefore must be neutral gray. Yellow and blue are complementary colors and when complementaries are medially mixed in proper amounts the result is always neutral mid-gray.⁷⁹

Crewdson's study was based on the mixture of color by the revolving disk.

Possible Attributes of Colored Yarn Mixture Compared to Disk Color Mixture

The additive mixture in fabric may possibly differ from the revolving disk color mixture in that it has a visual brilliance from the interplay of color,⁸⁰ and the "additive charm of vibration."⁸¹

XVII. THE EFFECT TEXTURE HAS ON COLOR IN FABRIC

Evans

Evans stated that different surface textures reflect the light differently; therefore, it would have a great influence upon the appearance of the color of a fabric.⁸²

⁷⁹Crewdson, op. cit., pp. 68, 69.

⁸⁰Ralph M. Evans, Movement to Color (New York: John Wiley and Sons, Incorporated, 1948), p. 86.

⁸¹Jacobs, loc. cit.

⁸²Ralph M. Evans, An Introduction to Color (New York: John Wiley and Sons, Incorporated, 1948), p. 289.

Wright

Wright developed in more detail the idea that Evans presented.

The depth of colour of a surface will depend in part on the extent to which the light penetrates into the surface, and this in turn will be governed by the dimensions, structure and refractive index of the material of which the surface is composed In addition to the effect on its colour, the physical structure of a surface will have a profound effect on its texture also. Let us consider two divisions of surfaces; glossy and mat. A glossy surface is one in which the medium forms a smooth and shiny surface from which much light is reflected.⁸³

Many times a glossy surface could be expected to reflect light from somewhere else into the observer's eye, and to that extent to modify the color of the surface.

With mat surface, the top-surface reflection will be diffusely distributed in all directions by the random orientation of the minute facets forming the top layer. Nevertheless, a major part of the light will still penetrate into the pigment layer, where it is partially absorbed and partially reflected to emerge in all directions as the colored component of the reflected light.⁸³

Watson

Watson, in a summarized form, stated essentially the same idea as Wright and Evans. He said that luster enhances the brightness and reflectancy of a color and possibly made it lighter. Whereas, the color of a rough and fibrous surface appeared deep and full.⁸⁴

⁸³Wright, op. cit., p. 22.

⁸⁴Watson, op. cit., p. 142.

CHAPTER III

ESTABLISHING CONTROLS AND PROCEDURES

In a research problem, where a comparison is to be made between two objects, all factors should remain constant except for the two factors being compared. In order to do this, many controls and a definite procedure should be established. In a study such as this, where color in woven fabric samples is being compared, a color system was first established. The type of weave, size and type of threads, size of samples, and the method and procedure of weaving also were established. In the judging of color samples, it was necessary to have controls established over the illumination in the judging room, the placement of the samples in relationship to the judges, and the length of time the judges were to look at the colors of the samples.

I. CHOOSING A COLOR SYSTEM TO FOLLOW

Spectrum colors were used for the basis of this study. There have been many divisions of the spectrum colors established by a number of different men in the color field. The Munsell division of the spectrum, into ten basic colors, has been chosen for this study. Munsell's color system was chosen for this research for two reasons. First, Munsell's system was

chosen because it was based on color as perceived by the eye, and secondly, his system of color has been one of the most widely accepted systems of color identification in the United States.¹ Munsell's system of color notation was used because all colors are designated by a rational nomenclature. The three Munsell coordinates were hue, value, and chroma.² His standards have been widely used for color identification and description by American industry, science, and the United States Government.

II. PRE-TESTING FOR SAMPLES

While this study was still in the planning stage, test samples were woven to reveal possible results upon which important factors could be determined.

Additive Color Mixture in Hand Woven Fabric

Test samples were woven to determine if it was possible

¹Olsen B. Buchmann, "The Objective Measurement of Colour and Color Changes," Transactions of the Danish Academy of Technical Science, No. 4 (Contributions from the Danish Institute for Textile Research, No. 11, Kobenhavn, Denmark: 1950), p. 25; and Faber Birren, New Horizons in Color (New York: Reinhold Publishing Corporation, 1955), p. 192.

²Munsell uses the term "chroma" to designate saturation in color. Recently, through color language standardization, the term "saturation" has become more accepted. In this report the term "saturation" will be used except when quoting or directly referring to Munsell when the word "chroma" will be used.

to obtain an additive color mixture in a hand woven fabric. When this was found possible, other pre-testing continued.

Size of Threads

Different sizes of threads were used in the test samples to determine the best size of thread to obtain additive color mixture in hand woven fabric.

Control threads. Different sized threads for the control samples were tested to determine the best and most effective size for additive color mixture in hand woven fabric.

Textured threads. Different textured yarns were tried to find those that best matched the control yarns in size, and construction, and which would give the desired effect of sheen or non-sheen.

Size of Sample

Samples were woven in one, two and three inch squares to determine the minimum size sample in which additive color mixture could be seen successfully.

Finding the Best Weave

Simple weaves were used since this was a problem of color rather than fabric design and complex weaves. Different types of weaves were tested to find the weave that best brought up equal amounts of warp and filling yarns to the surface.

These treadlings were tried with the following results.

Plain weaves.

- A. Tabby: 1-3* Over one thread and under
 2-4 the next.

Result: too much warp showed.

- B. Basket 1-4 Over two threads and
 2-3 under the next two.

Result: a more equal amount of warp and
 filling yarns showed.

Twill weave.

- A. First weave tried: 1-
 2-
 3-
 4-

Over three warp yarns and under one.

Result: Too much filler yarn showed.

- B. Second weave tried: 1-2-3
 2-3-4
 3-4-1
 4-1-2

Under three warp yarns, over one.

Result: Too much warp yarn showed.

- C. Third weave tried: 1-2
 2-3
 3-4
 4-1

Over two and under two warp yarns. Next shot
over one of the last yarns and also over the next.

Result: A more equal amount of warp and filling
yarns showed.

*The number represents the number of the heddle raised during a shot on a loom threaded the same as described in this chapter on page 50.

III. CONTROLS OF THE YARNS

Control of Color in the Yarns

In obtaining a controlled group of samples, it was necessary to control the colors of the yarns. The ten basic colors of the Munsell gamut at their most saturated point were used. The ten basic Munsell colors are: red, yellow-red, yellow, green-yellow, green, blue-green, blue, purple-blue, purple, and red-purple. Use was made of commercial yarns when they matched the Munsell gamut; the rest of the yarns were dyed to match in color. The colors used in the commercial yarns were: in the rayon textured yarns: red, yellow-red, yellow, green, blue-green, purple and red-purple. In the cotton textured yarns the following colors were used: red, yellow-red, yellow, green and blue-green. The following colors were dyed to approximate, as closely as possible, the Munsell color wheel: in the rayon textured yarns: green-yellow, blue, and purple; in the cotton textured yarns: green-yellow, blue, purple-blue and red-purple.

Control of the Type of Yarns Used

A single type of warp yarn was chosen to be used in all the samples. Three types of filling yarns were chosen; one for the control samples, and two different textured yarns for the sheen and non-sheen textured samples.

Warp yarns. All the warp yarns were a mercerized combed cotton yarn. It was number 5 of the Lily Mills Company.

Filling yarns. The yarn chosen for the control samples was the same as the warp yarn, a mercerized combed cotton.

The textured yarns for the experimental samples were from Butterworth Company and were of two types. Each type was woven into a set of samples to be compared to the control samples. The yarn for the non-sheen textured samples was a bouclé, non-sheen cotton ratiné yarn. This will be referred to hereafter as cotton ratiné. This textured yarn is a roughly carded cotton where fibers intermingle and cross each other. It has a down surface, and in its natural condition, produces very little luster, hence it is lacking in luster and brightness.³ This cotton ratiné never has a sheen.

The yarn for the textured samples with sheen was a bouclé sheen rayon ratiné. This will be referred to hereafter as rayon ratiné. This rayon ratiné always has a sheen. The raw materials differ extremely as to luster. Rayon is a smooth unicellular fiber and therefore has high light reflectancy causing luster.

³William Watson, Textile Design and Colour (New York: Longmans Green and Company, 1937), p. 142.

IV. CONTROLS OF WEAVES AND SAMPLE SIZE

The Two Weaves Used for the Samples

Plain weave. For the plain weave samples, the second weave tried in the pretesting⁴ was used because it brought up a more equal amount of warp and filling yarns. The weave proceeded as follows. The first filling yarn proceeded over the first warp yarns and under the next two. The second yarn proceeded under the first two warp yarns and over the next. The rest were repeats of the first two filling yarns. The treadling for the loom was: 1-2, 3-4.

Twill weave. For the twill weave samples, the third weave tried in the pretesting was used because it brought up a more equal amount of warp and filling yarns. The weave proceeded as follows. The first shot of the yarn proceeded over the first two threads and under the third and fourth yarns. The second shot of yarn proceeded under the first warp yarn, over the second and third, and under the fourth. The third proceeded under the first two warp yarns, over the third and fourth. The fourth filling yarn proceeded over the first warp yarn, under the second and third, and over the

⁴Discussion of pretesting weaves is located in this chapter on pages 45-46.

the fourth. The rest was a repeat of these four yarns. The treadling of the loom was as follows: 1-2, 2-3, 3-4, 4-1.

Size of the Samples

In pretesting, it was found that the two inch square sample was the minimum size in which additive color mixture could be seen successfully. Therefore, the two inch square sample size was decided upon. In order to see a full two inch square in the mounting frame, the samples were woven in two and one-half inch by two and one-fourth inch rectangles.

V. PROCEDURES OF THREADING THE LOOM AND WEAVING

The samples were all woven at the same time on the same warp to assure samples of equal size, density and color.

Threading the Loom

A loom with four harnesses was used to weave the samples. The heddles were threaded from left to right, front to back, in the order of: one, two, three, four, continuously across the loom. The reed was one of twelve dents to the inch. There were two threads to a dent making the warp twenty-four threads to an inch.

The warp was twenty-six inches wide. The yarns were in ten individual groups of the ten basic Munsell colors across the warp. From left to right were red through red-purple.

Each color had a two and a half inch width except for the two end colors. The two end colors had a two and three-fourths inch width to allow for the pull-in on the edges of the fabric when woven.

Procedure for Weaving the Samples

The samples were woven by taking one Munsell color and weaving samples with the three different types of yarns and the different weaves, then another color was used. The following was the procedure for one color:

- (A) Two and one fourth inches of one color was woven of plain weave in the mercerized cotton control yarn.
- (B) Two and one fourth inches of the same color was woven of twill weave in the mercerized cotton control yarn.
- (C) Two and one fourth inches of the same color was woven of plain weave in the textured cotton ratiné yarn.
- (D) Two and one fourth inches of the same color was woven of twill weave in the textured cotton ratiné yarn.
- (E) Two and one fourth inches of the same color was woven of plain weave in the textured rayon ratiné yarn.
- (F) Two and one fourth inches of the same color was woven of twill weave in the textured rayon ratiné yarn.

Each of the procedures was repeated for the ten different basic Munsell colors making every possible combination of the ten colors; with every possible combination of the three

yarns in the two different weaves used. This made a total of six hundred samples for study.

Due to the fact that so many samples, each with their many interesting facets, would make this study much too lengthy, the three hundred plain weave samples were the only ones used in the research of this study. At some later date, research should be continued on the twill samples and the other interesting facets of the total group of samples.

VI. CONTROLS AND PROCEDURES FOR JUDGING

Controls and procedures were established for the judging of the samples in order to keep all factors as constant as possible.

Method of Judging the Samples

Since the purpose of this research was to determine what could be expected to be seen visually with certain combinations of colors and textures, and in consideration of the discussion in the review of literature⁵ on this point, the samples were judged visually by qualified judges.

Mr. Daniel Smith at the Interchemical Corporation, Color Center in New York City personally advised visual

⁵A discussion of the mechanical and human eye methods of judging are located in the Review of Literature, Chapter II, pages 21-28.

judging.⁶ He, as well as several sources,⁷ recommended visual judging for this type of research involving a problem in which the results of the study will be to determine the changes or differences in the samples that could be expected to be seen. Many valuable research problems in color have been judged by macroscopic examinations.⁸

Characteristics of a normal human eye have been standardized by the International Commission on Illumination and ratified by twenty-six nations.⁹

The Room Used for the Judging

The room used for judging the samples in this study was a room primarily used for judging color in foods. The windows had opaque blinds and draperies to exclude all natural light. The draperies, walls and ceiling were all a neutral gray, value seven on the Munsell value scale. The floor was

⁶Daniel Smith, personal interview, Interchemical Corporation, Color Center, Central Research Laboratories, 432 West 45th Street, New York, 36, New York.

⁷Other sources discussing and recommending visual judging are elaborated on, and footnotes are cited in Chapter II, pages 25-28.

⁸Research problems in color that have been judged by macroscopic examination are discussed and footnoted in the Review of Literature, Chapter II, pages 26-28.

⁹Emma Baker, "Experiments on the Aesthetic of Light and Colour," University of Toronto Studies, II (Ed. A. Kirschman, Toronto: Published by the Librarian of the University of Toronto, 1907), p. 26.

a gray knotted design in asphalt tile. The counters, upon which the samples were placed, were gray formica, value eight. There appeared to be no strong colors influencing the color of the samples.¹⁰ The room used for judging was long and fairly narrow in shape. The gray formica counters lined the walls on each side.

The Illumination of the Judging Room¹¹

The judging room was completely illuminated by artificial light. This method gave a controlled and constant light. There were two large overhead fluorescent lights with four, four foot long fluorescent tubes. These lights were nine feet from the floor and six feet from the counter on which the samples were placed for the judging. The lights gave a constant all over light which is important of judging. These fluorescent lights were General Electric's forty watt, deluxe cool white. They approximated, as closely as was possible, natural day light.

Along the counters, at the end of which the samples were to be judged, were four, one and a half foot, fifteen

¹⁰The point on colors of a room having influence on a color when being judged is discussed in the Review of Literature, Chapter II, page 33.

¹¹Standards for the illumination of the room for judging was discussed in the Review of Literature, Chapter II, pages 28-32.

watt, deluxe, cool white fluorescent bulbs. They were sixteen inches apart. The light bulb at the end of the counter was the closest and most direct light on the samples. It was fifteen inches from the samples. The other three counter lights lighted the viewing channel from the judges to the samples.

Sample Placement

The samples were placed at the end of the gray formica counter. They were set perpendicular to the floor against a neutral background. In each group of three samples of the same colors, the control sample was placed in the center with one textured sample on each side. This allowed the judges to make a close comparison of the textured samples to the control sample. The conditions for all samples were the same. The object was to determine the changes in the samples created by the textured yarns.

The samples were placed at eye level of the judges when they were seated. The judges sat fifteen feet¹² from the samples. This was a distance at which an additive mixture of the colors in the yarns could best be achieved in the eyes of the judges.¹³

¹²Distance established from the Review of Literature and discussed in Chapter II, pages 32-33.

¹³Discussed in detail in Chapter II, page 35.

Order of Judging and Method of Recording Judges' Observations

The three qualified¹⁴ judges observed each group of three samples and judged them in the following order established in the review of literature.¹⁵

First, the color of the control sample was determined and given a Munsell Color Notation of hue, value and chroma.¹⁶ The notations for the control samples were recorded on the judging charts.¹⁷

The next step was to compare the textured samples to the control samples. (A) First the hue of the two textured samples was compared to the hue of the control sample, (B) secondly the value, and (C) third, the saturation was compared. Each judge recorded his observation on his own judging sheet.

Judging the Hue

A zero (0) was placed in the appropriate box to indicate no-change, if the hue of the textured sample appeared

¹⁴The qualifications of the judges are discussed in the appendix.

¹⁵Order for judging the samples was discussed in the Review of Literature in Chapter II, page 34.

¹⁶Explanation of the Munsell Notations and order of judging is discussed in the Review of Literature, Chapter II, pages 9-10, 34.

¹⁷Examples of the judges charts are located in the appendix.

to be about the same as the hue of the control sample. If the color favored another hue than that of the control, an arrow head plus the Munsell letter of the color was placed in the space: (>R). This indicated that the sample very closely favored red. Many times a Munsell color number was also given for finer differences when the colors were close: (>R 7.5).

Judging the Value

The judges recorded a zero (0), a plus (+) or a minus (-) in the appropriate space for each textured sample. The zero indicated no change in value from the control sample. The plus indicated that the textured sample was of a lighter value and was higher on the Munsell value scale than the control sample. The minus indicated that the judges felt that the textured sample was lower on the Munsell value scale than the control sample.

Judging the Saturation

The changes in saturation were recorded much the same way as the value. The zero (0), was used to indicate no change in saturation from the control sample. The plus (+) indicated that the textured sample had greater saturation of color than did the control. The minus (-) indicated less saturation of color in the textured samples in relationship to the control sample with which it was being compared.

Controls to Prevent Eye Strain and Fatigue

It was necessary to prevent eye strain and fatigue when observing and judging color.¹⁸ Each group of three samples, the control and the two textured, all of the same colors of yarns, were observed at the same time, and the judges' impressions recorded as soon as possible. If a decision could not be made right away, the judges would close their eyes, or look around the room for a minute to rest the nerves of the eyes which control color vision.¹⁹ Because of the caution that must be taken with the eyes to assure that the judges were seeing the correct color, each group of three samples took approximately seven minutes to judge. Very few groups of samples could be judged at the same sitting for the eyes became easily strained and tired.

When the judging was completed, the information from the three judging sheets was compiled into tables called Series A. These tables recorded the judges' impressions of the changes in the samples as compared to the control samples.²⁰

¹⁸Much discussion was found in the Review of Literature as to the great importance of avoiding eye strain when judging color. Chapter II, pages 35-36.

¹⁹There was much discussion in the Review of Literature concerning the eyes during judging. Chapter II, pp. 36-37.

²⁰The Series A tables are located in the appendix.

Another set of tables, Series B,²¹ recorded the Munsell notations given the control samples, plus a summarized version of Series A tables.

The following chapter shows the analysis of the data as it was compiled from the tables listed in Series A and B.

²¹The Series B tables are located in the appendix.

CHAPTER IV

TABLE AND GRAPHIC ANALYSIS OF TWO
GROUPS OF SAMPLES

The color harmonies of the samples were divided into two groups. They were samples in which the warp and filling yarns were of: (1) complementary colors, and (2) samples in which the yarn colors were two hue steps apart on the Munsell color wheel.

The information recorded by the judges on the judging charts was compiled into table form in order that each judge's notation, on each sample observed, could be seen together with the other judges' notations on the same samples. There were twenty tables which recorded the judges' notations. The first ten tables were designated as series A Tables, A-I through A-X, and the second ten as series B Tables, B-I through B-X.

A third group of tables designated as series C Tables was compiled as a compendium of Tables series A and B, which recorded data necessary for the study of the two groups aforementioned. Each of the groups was analyzed according to their changes in hue, value, and saturation. The graphs which accompany each series C Table aid in the analysis of the table data.

I. THE PURPOSE AND CONTENT OF TABLES

A, B, AND C

Series A Tables¹

The series A tables recorded the notations of each judge on all the textured yarn samples. The information was taken directly from the judging sheets.² The purpose of the series A tables was to facilitate the analysis of each of the three judges' notations separately as compared to the other two judges' opinions. One table was established for each different filling yarn color: red, A-I; yellow-red, A-II; yellow, A-III; green-yellow, A-IV; green, A-V; blue-green, A-VI; blue, A-VII; purple-blue, A-VIII; purple, A-IX; red-purple, A-X.

Series B Tables³

The series B tables recorded the Munsell notations given to the control samples by the judges, plus a summarized version of the judges' notations on the textured samples. The purpose of these tables was to facilitate comparison between the textured samples and the control samples. There was established a separate table for each filling yarn color:

¹Series A tables are located in Appendix.

²Judging sheets are located in the Appendix.

³Series B tables are located in the Appendix.

red, B-I; yellow-red, B-II; yellow, B-III; green-yellow, B-IV; green, B-V; blue-green, B-VI; blue, B-VII; purple-blue, B-VIII; purple, B-IX; red-purple, B-X.

Series C Tables⁴

The Series C tables recorded only that information from the series B tables pertaining to the samples needed in the two groups that were used for comparison and study. Only two groups of samples were used for comparison as more would have made the report much too lengthy. It was felt that these two chosen groups would give an adequate representation of all the samples.

First group of samples under study. Samples in the first group were of complementary hues. Complementary harmonies result when two hues are directly opposite each other on the color wheel. The information recorded from these samples was compiled in Table C-I. The samples⁵ were: R-BG; YR-B; Y-PB; GY-P; G-RP; BG-R; B-YR; PB-Y; P-GY; and RP-G.

⁴The series C tables are located in Chapter IV. Table C-I is located on page 69. Tables C-II, a and C-II, b for the second group are located on pages 81 -82.

⁵Henceforth in most cases the samples will be referred to by the first letter of the color or colors in the sample: R, red; RY, red-yellow; Y, yellow; GY, green-yellow; G, green; BG, blue-green; B, blue; PB, purple-blue; P, purple; and RP, red-purple.

Second group of samples under study. Group two was comprised of samples in which the hues of the warp and filling yarns were two hue steps apart on the Munsell color wheel. The information recorded on the series B tables pertaining to these samples was compiled on tables C-II-a and C-II-b. Table C-II-b recorded a continuation of table C-II-a. Two tables were needed because of the greater number of samples in this group than in the first. Table C-II-a contained data on samples: R-P; R-Y; YR-RP; YR-GY; Y-R; Y-G; GY-YR; GY-BG; G-Y; and G-B. Table C-II-b contained data on samples: BG-BY; BG-PB; B-G; B-P; PB-BG; PB-RP; P-B; P-R; RP-PB; and RP-YR.

II. EXPLANATION OF TABLES

The series A tables can be more easily understood after a discussion of the series B and C tables and, therefore, will be discussed after the presentation of the series B and C tables.

The Series B and C Tables

Series B and C tables have been divided into four main vertical divisions.

First vertical division of tables. In the first main vertical division at the left side of the tables will be seen the hues of the yarns in the samples. The filling yarn hue is represented on the left side, the warp yarn hue on the

right side. Each fabric sample has been represented within the horizontal lines.

Second vertical division of the tables. The second division of the tables labeled "Control Samples," was developed from the judges' selection of the Munsell notation of the hue, value and saturation of each particular control sample. A short discussion has been deemed advisable concerning the additional notations the judges felt necessary to make.

The term "gray" has been used to indicate that the judges felt the additive color in the sample almost achieved gray. This was particularly true in the group of samples having complementary colors.

The notation "d.d." has been used to indicate that the judges had difficulty in determining exactly which Munsell notation to give the particular sample. This was especially true of the group of complementary samples, since the colors so closely approximated gray.

Samples in which the yarn colors had extreme differences in value, such as in a sample with yarns of yellow and purple-blue, it was difficult to obtain an additive mixture of the color in the eye. In such cases the table carried the added notation of "h.b."; hard to blend.

Third and fourth vertical division of the tables. In

the third and fourth divisions of the tables, labeled "Textured Samples," have been recorded the combined decisions of the judges as to how they felt the textured samples varied from the control samples in the three attributes of hue, value and saturation. Many of the added notations described for the control samples in the second vertical division of the table, were also used for the textured samples. They were: "d.d.," difficult to determine the exact color; and "h.b.," hard to blend the hues of the yarns to an additive color mixture.

The hue change of the textured sample has been shown, in the first sub-column labeled "Hue," by a small arrow head and a letter representing a Munsell color,, e.g., > RP, indicating that the sample favored a red-purple hue.

Value changes have been recorded in the column headed by "V." Changes in saturation have been shown in the column headed by "S."

In these columns the sign minus (-), plus (+), and zero (0) have been used to indicate changes. If the textured sample has been judged lower in value or less saturated than the control sample, a minus sign has been used.

If the textured sample has been judged lighter in value or more saturated in color than the control sample, a plus has been used. The zero was used to indicate that there was little or no change in the textured samples compared

to the control samples.

If the notations have been placed in the center of the space, all the judges had agreed on that notation. If a notation has been placed in the center, and one in the lower right corner, the notation in the center will be indicative of the decision of the two judges, with the lower notation indicative of the decision of the third judge. If three notations have been shown in one box, one above the other, the character of the sample was difficult to determine, and all three judges differed in their decision.

Series A Tables

The symbols used in the series A tables were the same as those used in the series B and C tables. The difference in the tables is that the notations for only the textured samples have been given in tables A. Also, in the A tables, under each division of hue, value and saturation, three columns, numbered 1, 2, and 3, indicated each of the three judges' individual notations for each sample.

III. ANALYSIS OF COMPLEMENTARY COLORS IN ADDITIVE COLOR MIXTURE

The analysis of the samples from table C-I-a and b, was quite complex; therefore, the data from tables C-I will be shown visually on three graphs, one representing the hue

changes, the second representing the value changes, and the third, the saturation changes in this group of colors. By the use of these graphs the relationships and the changes of the textured samples from the control samples can be seen more easily.

In each graph the control sample has been represented by the red color, the non-sheen cotton ratiné texture by green and the rayon ratiné texture by blue.

The first of the three graphs, Figure 2, has recorded hue changes of the samples.⁶ This graph has visually shown how the textured yarns cause the textured samples to differ in color from the control yarn samples. Figure 3 has recorded the changes in value of the textured samples from the control samples.⁷ Figure 4, the third graph, has recorded the changes in saturation.⁸

⁶Figure 2 is located in Chapter IV, p. 71.

⁷Figure 3 is located in Chapter IV, p. 73.

⁸Figure 4 is located in Chapter IV, p. 77.

KEY TO THE TABLES

Capital letter or letters: = Munsell color name

Number under control sample columns: = Munsell notations
of hue, value or saturation.

Arrowhead with Munsell letter and number: >R = the textured
sample hue has favored that Munsell hue from the hue of the
control sample.

0 = no change in value or saturation from the control sample

+ = lighter value or more saturated than the control sample

- = darker value or less saturated than control sample

d.d. = the exact color of the sample was difficult to determine.

h.b. = the colors of the yarns were hard to blend to an
additive color mixture in the eye.

gray = the additive color mixture of the hue of the sample
very closely approximated gray.

br. = colors of the samples favored a brownish hue.

One symbol, number or letter in the center of the box: =
decision of all three judges.

Two symbols, numbers or letters in the box: = center symbol,
is the decision of two judges, the symbol in the
lower right corner, is the decision of the third judge.

Three symbols, numbers or letters in a box: = all judges
came to a different decision, all three judges opinions
are listed, one above the other.

TABLE C-I

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND CHANGES IN
THE TEXTURED SAMPLES FROM THE CONTROL SAMPLES

COMPLEMENTARY COLORS IN ADDITIVE
COLOR MIXTURE IN FABRIC

TWO STEPS AWAY CONTROL SAMPLES					TEXTURED SAMPLES						
COLOR OF YARNS			PLAIN COTTON			COTTON TEXTURED			RAYON TEXTURED		
FILLING	WARP		HUE	V	S	HUE	V	S	HUE	V	S
R	-	BG	7.5 RP gray	5	2	>RP 10.0 gray	-	+	>RP 10.0 gray	+	+
YR	-	B	2.5 PB	5	4	>YR 5.0 gray	0	0 -	>YR 5.0 gray	+	+
Y	-	PB	7.5 PB	5	4	h.b. >GY gray	0 ₊	0 ₊ -	gray >Y >GY	+	+
GY	-	P	7.5 P	4	4	>GY 2.5 br. -Y	+	-	>GY br- -Y	+	-
G	-	RP	2.5 RP	4	2	>G d.d -GY	0	0	>GY d.d.-G	0	0
BG	-	R	5.0 R d.d	5	8	>R gray 0	-	0 -	>BG d.d. 0	-	-
B	-	YR	2.5 YR	7	10	0 gray	-	-	0 gray	-	-
PB	-	Y	7.5 Y d.d.	7	4	>GY >PB >B gray	-	0 +	>GY >PB >B gray	-	0
P	-	GY	10.0 Y gray	6	2	>P gray	-	0 -	>P gray 0	0	0
RP	-	G	2.5 G	5	4	0 or R >R >RP gray	-	-	>R gray	-	-

Graph on Hue Changes, Figure 2

In Figure 2 each sample has been represented by a rectangle. The color of the yarns of the sample has been written above the rectangle; the name of the filling yarn color on the left, the warp yarn color on the right.⁹ The center portion of each rectangle represents the gray color which results when mixing complementary colors.

Observations made from the study of Figure 2. In the control samples the yarn colors blended to a color between the warp and filling yarn color. (1) Nine out of ten of the control yarn samples favored the hue of the warp yarn. (2) The only sample that favored the filling yarn hue was sample R-BG. This sample favored the red.

In the cotton textured ratiné samples the position of most of these samples was situated in the gray coloring section slightly favoring the filling yarn color. The filling yarn was the cotton textured ratiné. The only sample which favored the warp color was BG-R. The sample favored slightly the red color. The B-YR sample in this group most closely achieved a neutral gray.

The rayon textured ratiné samples mostly fell in the gray coloring section. Most of them slightly favored the

⁹In referring to the samples, the filling yarn color will be mentioned first, a dash and then the warp yarn color. This will be true throughout this study unless otherwise noted.

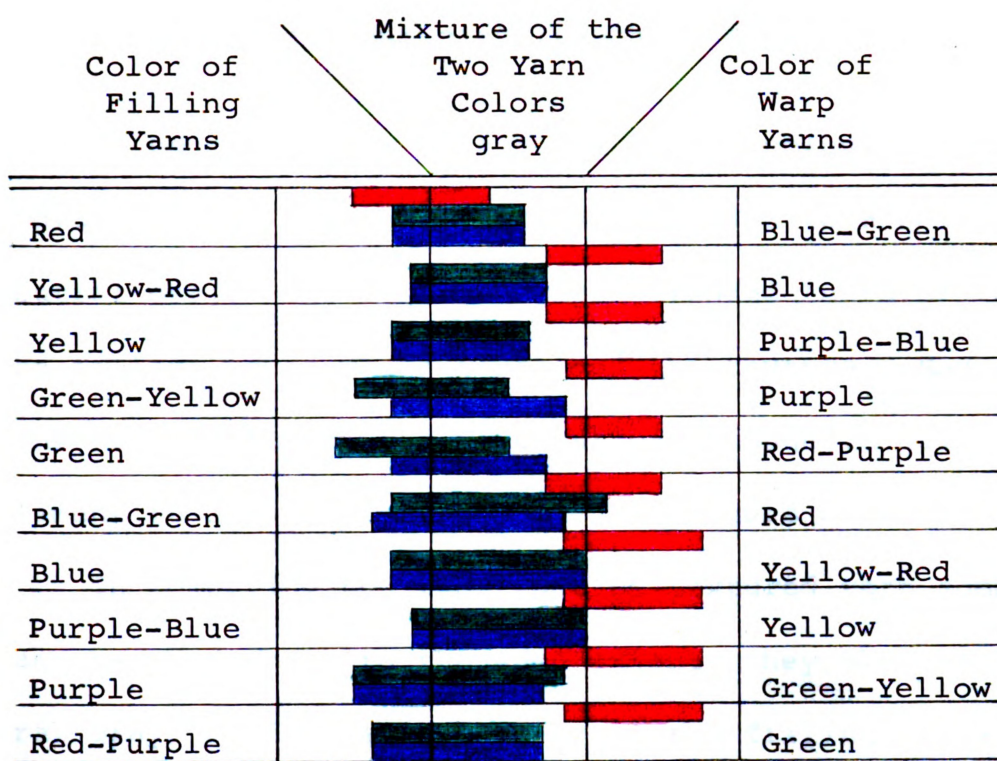


FIGURE 2

A COMPARISON OF THE HUE FAVORED BY THREE DIFFERENT
 TYPES OF YARNS IN FABRIC OF ADDITIVE COLOR
 MIXTURE WHEN WARP AND FILLING YARNS
 WERE OF COMPLEMENTARY COLORS

Control yarn samples, plain mercerized yarns: 
 Cotton textured samples, cotton mat ratiné yarns: 
 Rayon textured samples, rayon sheen ratiné yarns: 

filling yarn color as did the cotton texture. The B-YR sample in this texture also most closely achieved a neutral gray.

In conclusion at this point. In conclusion most of the colors of the samples additively blended to a color close to neutral gray. The control samples tended to favor the color of the filling yarns which contained the texture. Red was the only color that tended to be strong enough to pull its complement to its color tone while the others did not.

In comparing the two types of textured yarn samples, it was observed that, to the same extent, they blended to neutral gray, or favored the color of the filling yarns.

Graph on Value Changes, Figure 3

The amount of value change has been indicated in Figure 3, for the control samples and the textured samples.

Observations made from the study of Figure 3. Observations made from the study of Figure 3 were the following. In the control samples the value ranged from value 4/ to value 7/ on the Munsell value scale.

(1) Seven out of ten were value 4/ or 5/; value 4/; GY-P, G-RP: value 5/; R-BG, YR-B, Y-PB, BG-R, RP-G.

(2) One had a value of 6/ and two had the value of 7/. Value 6/ was sample P-GY; value 7/ was samples B-YR, PB-Y.

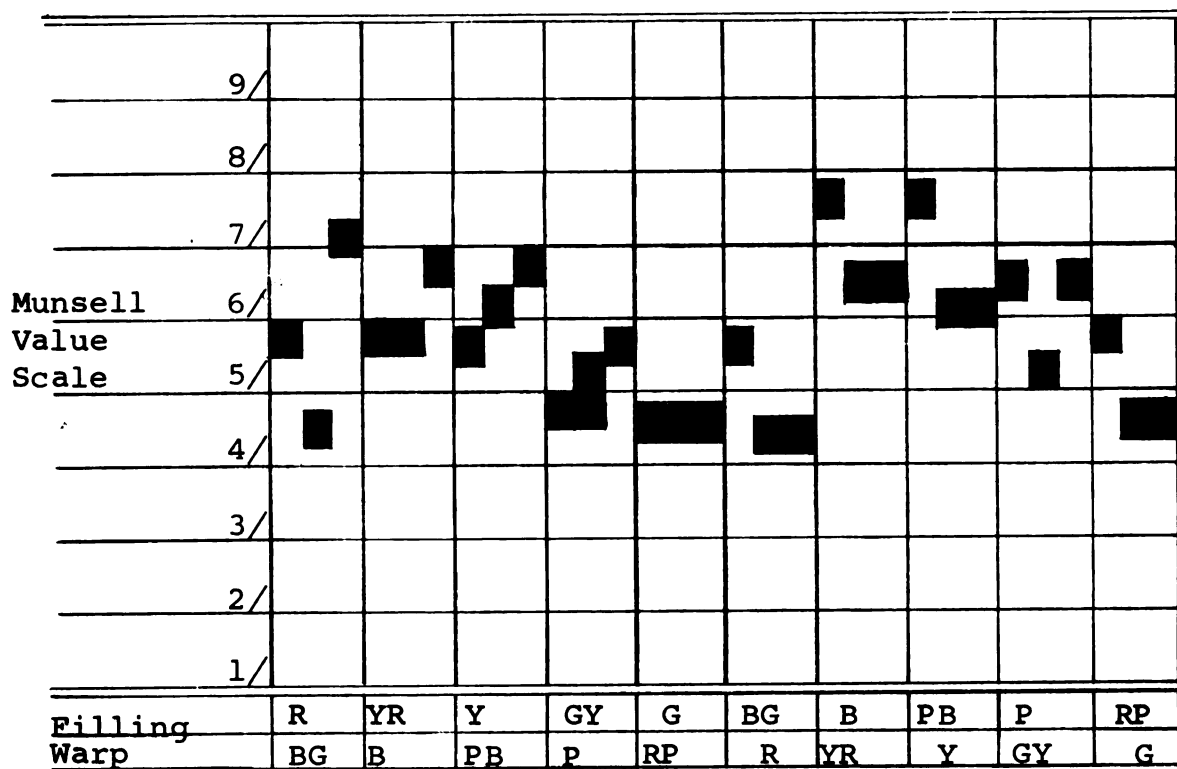


FIGURE 3

VALUE GRAPH OF THREE TYPES OF YARNS IN FABRIC
OF ADDITIVE COLOR MIXTURE WHEN THE WARP
AND FILLING YARNS WERE OF
COMPLEMENTARY COLORS

Control yarn sample, plain mercerized cotton yarn: 
Cotton textured samples, cotton mat ratiné yarn: 
Rayon textured samples, rayon sheen ratiné yarn: 

(3) Samples containing yarns of yellow and red seemed to have the higher value.

In the cotton textured ratiné filling yarn samples:

(1) the value in two samples was the same as the control samples: YR-B; G-RP. (2) The value of one was slightly lighter in value; Y-PB, and another one was undecided, (the same as or slightly lighter than the control); GY-P. (3) In six of the samples the value was darker than the control samples by one to one and a half value steps. They were samples; R-BG, BG-R, B-YR, PB-Y, P-GY, RP-G. (4) The samples having a value lighter than the control sample contained yellow and green-yellow textured filling yarns which intrinsically have a high value. (5) The largest drop in value was when red and blue-green were combined: R-BG, BG-R.

In comparing the rayon textured ratiné filling yarn samples with the control samples, the following was observed.

(1) Two samples stayed the same value as the control samples: G-RP, P-GY. (2) The value of four samples was lighter in value than the control samples: R-BG, YR-B, Y-PB, GY-P. In these four cases the value of the filling yarn color was by nature of a lighter value compared to other colors. (3) In four of the other samples the color of the rayon textured filling yarn was of a darker value than the control.

In these four cases it was the same value as the cotton textured samples.

In summary of value graph data. In summarizing the data of the value graph it was found that the range of value for this group of complementary color combinations was from a darkness of value 3/ to a lightness of value 7/ on the Munsell value scale.

A marked difference between the value position of the samples on the left side of the graph, compared to those on the right side was noted. It was important to remember that these samples were of complementary colors, therefore, the samples on the right were the same color combinations as those on the left. The only difference was that the colors were reversed in the filling and warp yarns.

On the left side of the graph, the textured samples appeared lighter than, or the same value as the control samples of the same colors. In these samples, the textured yarns were colors having a high value level at their most saturated level: R, YR, Y, GY.

The right side of the graph indicated that the textured yarn samples appeared darker in value than the control samples. In these samples, the textured yarns were those colors that rated lower on the value scale at their most saturated level: BG, B, PB, P, RP.

In conclusion at this point. Through this analysis, it became apparent that the textured yarns do change the value

of additive color mixture in fabric. This could be supported in this short summary of the observations made from Figure 2.

When the textured filling yarns were light in value, and the warp yarns dark, the samples appeared lighter than the control samples. In samples in which the filling textured yarns were dark in value and the warp yarns light, the textured samples appeared darker in value than the control samples. Thus, the value of the textured samples favored the value of the textured yarns.

When the rayon textured samples were compared to the cotton textured samples it was observed that in half of the samples the rayon texture was the same value as the cotton texture, and was of a lighter value in the other half. The cotton texture never appeared lighter in value than the rayon textures of the same color combinations.

Graph on Saturation Change, Figure 4

The amount of saturation change in the textured samples from the control samples has been shown in Figure 4. On the far left of the graph are the filling yarn colors, followed by the warp yarns and then the Munsell saturation chart on the right.

Observations made from the study of Figure 4. The following was observed from the study of Figure 4. In the

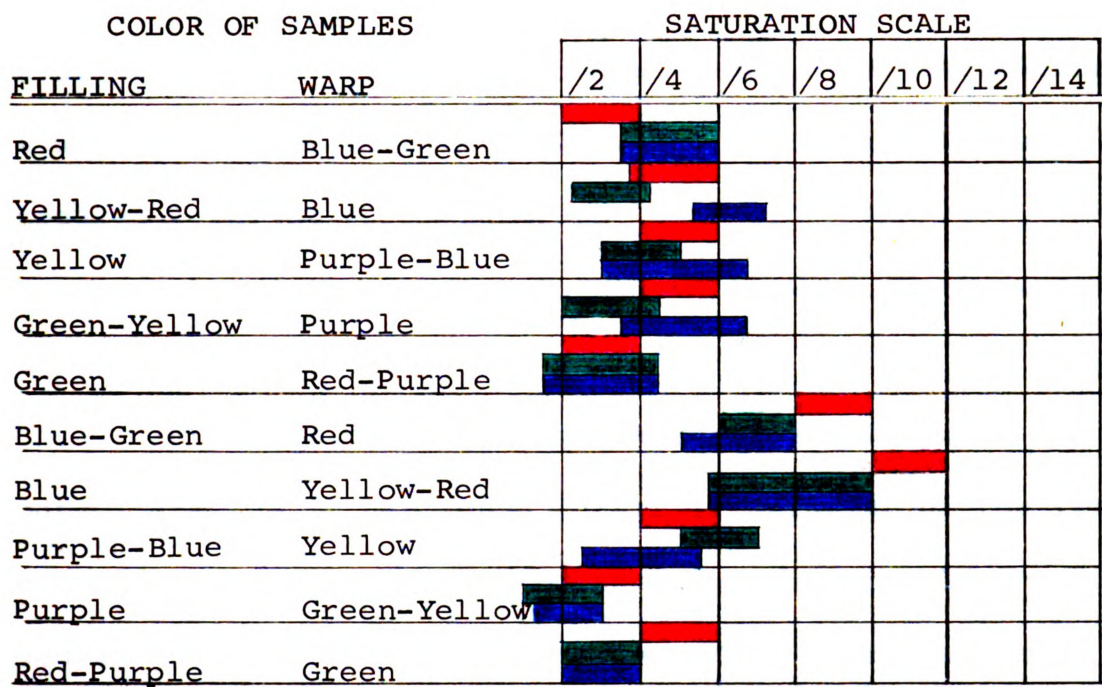


FIGURE 4

SATURATION GRAPH OF THREE TYPES OF YARNS IN FABRIC
OF ADDITIVE COLOR MIXTURE IN WHICH THE WARP AND
FILLING YARNS WERE OF COMPLEMENTARY COLORS

Control yarn samples, plain mercerized yarns: 
Cotton textured samples, cotton mat ratiné yarns: 
Rayon textured samples, rayon sheen ratiné yarns: 

control sample it was found that, (1) eight out of ten of the control sample colors had a saturation level of $\frac{1}{2}$ or $\frac{1}{4}$ on the Munsell Chroma chart. Those samples that exhibited a saturation level of $\frac{1}{2}$ were: R-BG, G-RP, P-GY; saturation $\frac{1}{4}$ were: YR-B, Y-PB, GY-P, RP-G, and PB-Y. (2) Two samples appeared to be at the saturation level of $\frac{1}{8}$ and $\frac{1}{10}$. These two samples had the colors red and yellow-red in the warp. They were: BG-R, B-YR.

In comparing the cotton textured samples with the control samples it was found that: (1) six out of the ten cotton textured samples stayed the same or were slightly less saturated than the control samples. They were samples: YR-B, Y-PB, G-RP, BG-R, PB-Y, and P-GY. (2) Three samples were markedly less saturated in color, especially those combinations of the same color that registered to be a high saturation level in the control samples. The samples were: GY-P, B-YR, RP-G. (3) Only one sample appeared to be more saturated than the control sample of the same color: R-BG.

In comparing the rayon textured samples with the control samples, it was found that: (1) three of these samples had about the same saturation as the control samples. They were: G-RP, PB-Y, and P-GY. (2) In two samples the saturation appeared much less than that of the two control samples. They were samples: B-YR, and BG-R. (3) Two other

samples also had a saturation level less than the control samples. These samples very closely approximated gray. They were samples: R-BG, and RP-G. (4) Three of the rayon textured samples appeared to be brighter in saturation than the control samples of the same colors. They were samples in which colors red, yellow-red and yellow appeared in the filling yarns. They were samples: R-BG, YR-B, and Y-PB. (5) Many of the samples carried the added notation that the saturation approximated "gray." This indicated that it was difficult to determine their exact saturation level.

Summary of saturation data. The range of saturation for complementary colors in additive color mixture was from a dullness of $/2$ and lower, to a brightness of $/10$ on the Munsell chroma chart. Most of the samples were in the lower than $/2$ to $/4$ range. This indicated that the colors closely approximated gray.

In comparing the textured samples with the control samples it appeared to the judges that the textured samples were generally the same or less saturated than the control samples of the same colors.

In comparing the two types of textured yarn samples of the same color combinations, it was found that they rated approximately the same in saturation level. One might be

a little lower than the other in one case and slightly higher in another.

In conclusion at this point. In conclusion, it was found that texture does change the saturation level of complementary colors in additive color mixture. It causes the textured yarn samples to appear the same or slightly duller in saturation than the control samples.

The rayon texture and the cotton texture did not appear to have any marked differences from each other in saturation level.

IV. ADDITIVE COLOR MIXTURE IN FABRIC IN WHICH THE COLOR OF THE WARP AND FILLING YARNS ARE TWO STEPS APART ON THE MUNSELL COLOR WHEEL

This section will report the findings of the effect of texture on additive color mixture in fabric samples in which the warp and filling yarns were two steps apart on the Munsell color wheel. Tables C-II-a and C-II-b* and the graphs in Figures 5,* 6,** and 7,*** will be studied for the analysis of these samples.

*Table C-II-a and C-II-b are located on pp. 81, 82.

*Figure 5 is located on p. 84.

**Figure 6 is located on p. 88.

***Figure 7 is located on p. 93.

TABLE C-II-a

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND CHANGES IN
THE TEXTURED SAMPLES FROM THE CONTROL SAMPLES

COLORS TWO STEPS APART ON MUNSELL'S COLOR WHEEL
IN ADDITIVE COLOR MIXTURE IN FABRIC

TWO STEPS AWAY CONTROL SAMPLES				TEXTURED SAMPLES						
COLOR OF YARNS		PLAIN COTTON			COTTON TEXTURED			RAYON TEXTURED		
FILLING	WARP	HUE	V	S	HUE	V	S	HUE	V	S
R	- P	5.0 RP	4	14	0	0	0 -	0 >R	0	+ 0
R	- Y	2.5 Y 10.0YR	8	12	>R	-	-	>R	0	+
YR	- RP	10.0 R	4	10	0	0 -	0	0 >Y	+	- 0
YR	- GY	2.5 Y	7	6	0	-	0	0	0	0
Y	- R	10.0 R	6	10	>Y	+ 0	0	>Y	+	+
Y	- G	10.0 GY	6	8	>Y -GY	+ 0	0	>Y >GY	+	+
GY	- YR	2.5 YR	7	10	>Y -GY	0 -	- 0	>Y >YR	+	0 +
GY	- BG	5.0 G	6	2	>GY	+ -	0 -	>GY	+	+
G	- Y	5.0 GY	7	8	0	0 -	0	0	0	0
G	- B	7.5 BG	4	6	>G	0 -	- 0	>G 0	0 -	- 0

TABLE C-II-b

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND CHANGES IN
THE TEXTURED SAMPLES FROM THE CONTROL SAMPLES

COLORS TWO STEPS APART ON MUNSELL'S COLOR WHEEL
IN ADDITIVE COLOR MIXTURE IN FABRIC

TWO STEPS AWAY COLOR OF YARNS			CONTROL SAMPLES			TEXTURED SAMPLES					
			PLAIN COTTON			COTTON TEXTURED			RAYON TEXTURED		
FILLING	WARP		HUE	V	S	HUE	V	S	HUE	V	S
BG	-	GY	7.5 GY	7	4	>GY	-	+	>G	-	+
BG	-	PB	7.5 PB	6	12	0 >PB 5.0	-	0	>BG	-	0
B	-	G	5.0 G	5	8	0 >BG	-	0	>BG	-	0
B	-	P	2.5 P	4	8	>PB	0 +	-	>PB 0	0	0
PB	-	BG	2.5 PB	4	4	0	0	0 +	0	0 +	0 +
PB	-	RP	7.5 RP	3	8	>P 2.5	0	-	>P 7.5 >PB	0 +	0 -
P	-	B	5.0 PB	4	12	>P -PB	0 +	-	>P >PB	0	-
P	-	R	2.5 R	4	14	>RP	0	-	>RP >R	0	-
RP	-	PB	10.0 PB	3	10	>RP -P	0	0	>RP >P	0 +	0
RP	-	YR	2.5 YR	6	12	>R 10.0	- 0	-	>R	-	+ 0

Tables C-II-a and C-II-b contain information taken from Tables A which pertain to the samples under study in this section. Because each sample was compared to two samples, colors two hue steps away on each side of its position, there were twenty samples for comparison. Because of this number, two tables were needed. Table C-II-a, followed by C-II-b should be read exactly as discussed earlier in this chapter on page 68.

The data in the C-II tables was further broken down and may be observed in Figures 5, 6, and 7. Figure 5 clearly showed the hue pattern of this group of samples. Figure 6 showed the value pattern and Figure 7 the saturation pattern of these samples. With a complete breakdown such as this, each phase could be closely studied and analyzed.

Graph on Hue Changes, Figure 5

In Figure 5 each rectangle represents a sample. The filling yarn colors are on the left, the warp yarn colors are to the right of the rectangles. The section in the middle represents the color in between the two colors on the color wheel.

Observations made from the study of Figure 5. In the control samples it was found that: (1) nine out of the twenty samples blended to a color approximately halfway between the two colors. They were samples: R-P, R-Y, YR-RP, YR-GY, Y-G, GY-BG, G-Y, G-B, and P-B. (2) Ten out of the twenty

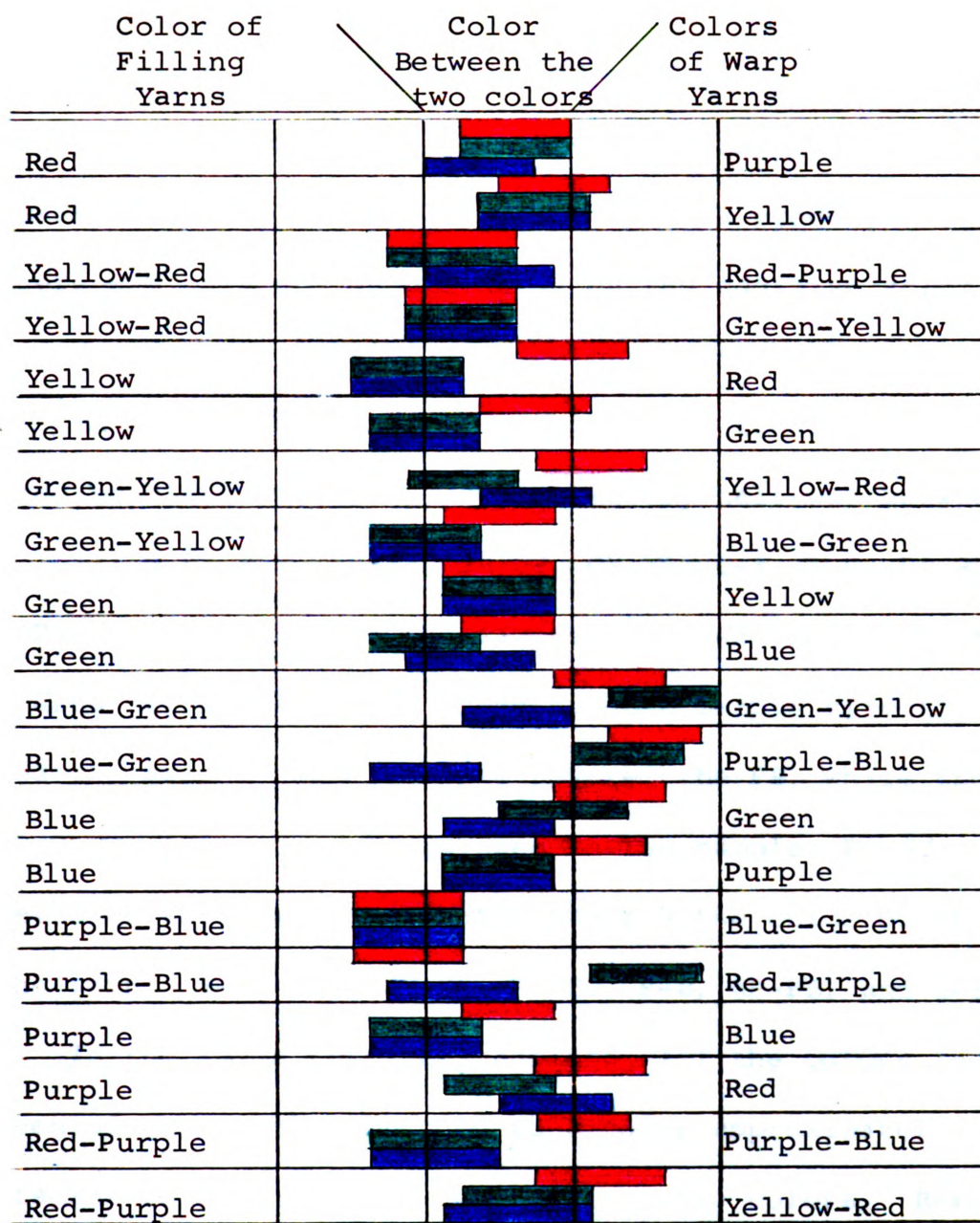


FIGURE 5

A COMPARISON OF THE HUE FAVORED BY THREE DIFFERENT TYPES OF YARNS IN FABRIC OF ADDITIVE COLOR MIXTURE WHEN WARP AND FILLING YARNS WERE TWO COLOR STEPS APART ON THE MUNSELL COLOR WHEEL

Control yarn samples, plain mercerized yarns:
 Cotton textured samples, cotton mat ratiné yarns:
 Rayon textured samples, rayon sheen ratiné yarns:

samples blended to a color in which the warp yarn color was more predominate: Y-R, GY-YR, BG-PB, B-G, B-P, PB-RP, P-R, R-PB, and RP-YR. In two of the above-mentioned samples, BG-PB, and PB-RP, the warp yarn color was very much predominate.

(3) There was only one sample in which the additive color mixture favored the filling yarn color: PB-BG.

In the cotton textured samples; (1) ten of the samples appeared to blend to the hue approximately half-way between the two colors; R-P, R-Y, YR-RP, YR-GY, GY-YR, G-Y, B-P, PB-RP, P-R, RP-YR. (2) Three of the samples favored the color of the warp yarns but in different amounts. B-G sample slightly favored the green. BG-PB sample favored the PB, while the GY color was very strongly favored in the sample; BG-GY.

(3) Seven of the samples slightly favored the color of the filling yarn: Y-R, Y-G, GY-BG, PB-BG, P-B, RP-PB, and G-B.

In the rayon textured samples: (1) the colors in thirteen of the samples blended to a color approximately equidistant between the two hues of the yarn colors. R-P, R-Y, YR-RP, YR-GY, GY-YR, G-Y, G-B, BG-GY, B-G, B-P, PB-RP, P-R, and RP-YR. (2) None of the samples favored the hue of the warp yarns. (3) Seven of the colors slightly favored the hue of the filling yarns. They were samples; Y-R, Y-G, GY-BG, BG-PB, PB-BG, P-B, RP-PB.

In summary of hue graph data. In summarizing the data on hue it was found that in the blending of the yarn colors in the control samples, nearly half of the samples blended to a hue halfway between the two colors in the samples. Only one sample favored the filling yarn color. Half of the samples favored the warp yarn color.

In the cotton ratiné textured samples, half of the samples blended to a color between the two colors. Only three favored the warp yarn color and seven favored the filling yarn color.

In the rayon ratiné textured samples, more than half of these samples blended to a hue between the two colors of the yarns. None favored the warp yarn color and seven favored the filling yarn color.

In conclusion at this point. The following possible conclusions could be drawn from the data on the effect of hue in additive color mixture in samples two hue steps apart: The additive color mixture in the control samples favored the hue of the warp or the mixed color of the two hues. In samples with texture, the color of the sample favored the color of the filling textured yarn or the mixed color of the two hues. This pointed out that the textured yarns slightly changed the color of the samples to more closely resemble the color of the textured yarns.

Graph on Value Change, Figure 6

Figure 6 shows, in graph form, the changes in value for the group of samples in which the colors of the yarns were two steps apart on the Munsell color wheel.

Observations made from the study of Figure 6.

In the control samples it was observed that: (1) only one sample in this group of samples showed a value as light as 8/ on the Munsell value chart. Sample: Y-R. (2) Four samples had a value of 7/; YR-GY, GY-BG, G-Y, and BG-GY. All of these light valued samples contained the color of yellow which has normally a high value level due to its high light reflective ability. (3) Five samples had a value of 6/. They were: Y-R, Y-G, GY-BG, BG-PB, RP-YR. Most of these samples also contained some yellow. (4) Only one sample had the value of 5/; B-G. (5) Seven of the samples had the value of 4/. R-P, YR-RP, G-B, PB-BG, PB-RP and RP, PB. All of these samples contained blue and purple. (6) Two of the samples had the value of 3/; PB-RP, RP-PB. These two color combinations had the lowest value.

In comparing the cotton textured samples to the control samples, the following was observed. (1) The value of twelve of the cotton textured samples appeared to approximate the same value of the control samples. They were samples: B-P, P-B, R-P, GY-BG, PB-BG, PB-RP, P-R, RP-PB, YR-RP, GY-YR, G-Y, G-B.

MUNSELL VALUE SCALE

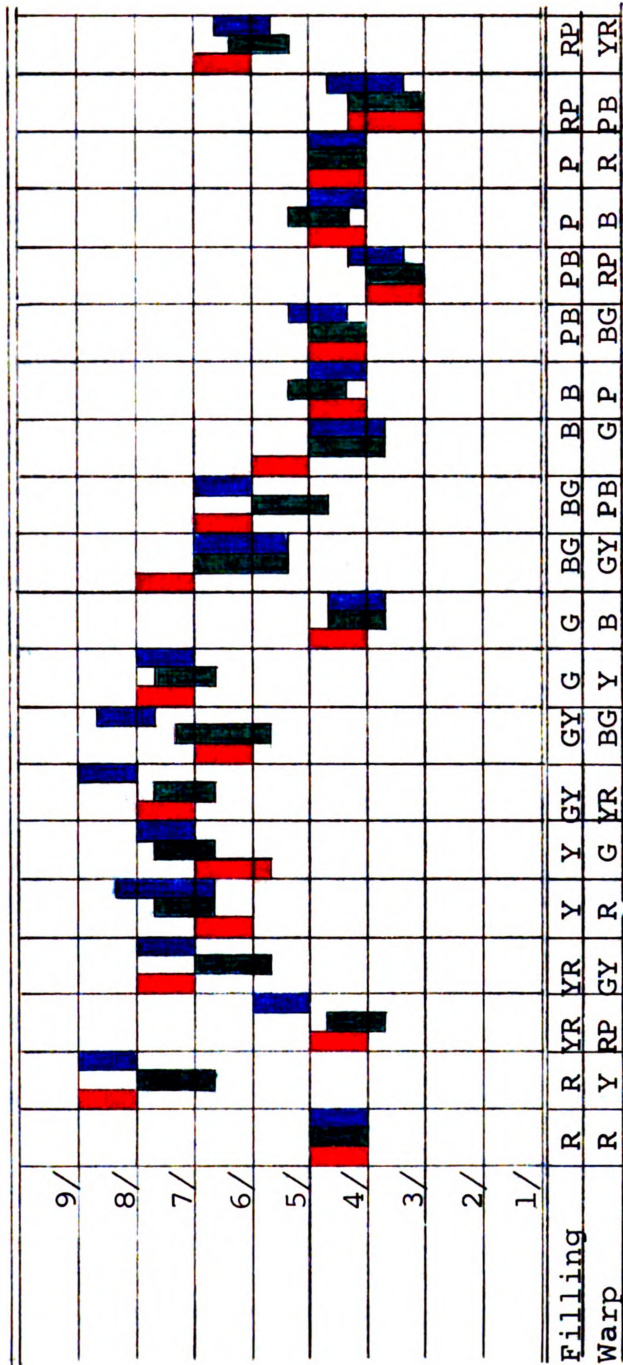


FIGURE 6

VALUE GRAPH OF THREE TYPES OF YARNS IN FABRIC OF ADDITIVE COLOR WHEN THE WARP AND FILLING YARNS WERE TWO STEPS APART FROM EACH OTHER ON THE MUNSELL COLOR WHEEL

- Control yarn sample, plain mercerized cotton yarn: ■
- Cotton textured samples, cotton mat ratiné yarn: ■
- Rayon textured samples, rayon sheen ratiné yarn: ■

(2) Only two of the cotton textured samples appeared to be noticeably lighter in value than the control samples of the same colors: Y-R, Y-G. (3) Six of the cotton textured samples appeared noticeably darker in value than the control samples: R-Y, YR-GY, BG-GY, BG-PB, B-G, RP-YR.

The value rating in thirteen of the rayon textured samples appeared to be similar to the value of the control samples of the same color. (1) Out of these thirteen rayon textured samples some appeared to be a little closer in value than others. They were samples: PB-BG, PB-RP, RP-PB, R-P, R-Y, YR-GY, BG-PB, B-P, P-B, P-R, G-Y, G-B, RP-YR. (2) Five samples of the rayon textured yarns appeared noticeably lighter in value than the control samples: YR-RP, Y-R, Y-G, GY-YR, GY-BG. (3) Only two samples of the rayon textured yarns appeared markedly darker in value than the control samples of the same colors: BG-GY, B-G.

When the two different types of textured samples were compared it was found that: (1) thirteen of the samples were nearly the same value as each other. They were samples: Y-R, Y-G, PB-BG, PB-RP, RP-PB, G-Y, R-P, G-B, BG-GY, B-G, P-R, B-P, and P-B. (2) Seven of the rayon textured samples were noticeably lighter than the cotton textured samples of the same colors: R-Y, YR-RP, YR-GY, GY-YR, GY-BG, BG-PB, and RP-YR. (3) none of the rayon textured samples were

noticeably darker in value than the cotton textured samples of the same color combinations.

Summary of the value graph data. In summary, the following has been interpreted and analyzed from the above information.

The range of value for this group of samples is from a low of 3/ to a high of 8/ on the Munsell value scale. Most of the samples rated value 4/, 6/, and 7/.

Samples on the left side of the graph contained yellow-red, yellow, and green-yellow. They rated high on the value scale: values; 6/, 7/, and 8/. Samples on the right side of the graph contained blue, purple-blue and purple. They rated low on the value scale: values; 3/ and 4/. In both the control and textured groups of samples, the samples containing the color combination of red-purple with purple-blue rated at the darkest value of all the samples, value 3/.

The cotton textured samples appeared to be the same or darker in value than the control samples of same colors. Twelve samples were approximately the same value, six samples were darker than the control samples, and only two cotton textured samples were lighter than the control samples.

The rayon textured samples, on the whole, were judged to appear the same or lighter in value than the control samples. Seven of the rayon textured samples were rated lighter than

the control, while eleven were approximately the same value. Only two rayon ratiné samples were rated darker in value than the control.

When the rayon textured samples were compared to the cotton textured samples, the rayon textures were lighter in value. The rayon had seven samples that appeared lighter in value, thirteen about the same in value and none lower in value than the cotton texture.

Conclusions at this point. In drawing some conclusions from the analysis of the data of Figure 6, it has appeared that texture can change the value of additive color in fabric.

Rayon texture generally tended to appear the same or lighter in value than the control samples of the same color combination. The cotton texture generally appeared the same or darker in value than the control samples of the same color combinations.

In all three groups of samples it appeared that samples containing colors which registered high on the value scale at their most saturated level, tended to pull the value level of the sample high. Samples containing colors that registered low on the value scale at their most saturated level tended to give the sample a dark value rating. The inherent value of the color of the textured yarn was most influential. Due to the high light reflectancy of rayon, the rayon samples appeared to be lightest.

Graph on Saturation Change. Figure 7

The changes in saturation for this group of samples in which the color of the yarns are two steps apart on the Munsell Color Wheel have been recorded on the graph in Figure 7.

In the control samples of this group of samples, the following data was observed. (1) Only two control samples showed a saturation level as bright as /14: R-P, P-R. (2) Four samples showed a saturation level of /12: R-Y, BG-PB, P-B, RP-YR. (3) Four samples showed a saturation level of /12: YR-RP, Y-R, GY-YR, RP-PB. (4) Five of the control samples appeared to have a saturation level of /8: Y-G, G-Y, B-G, B-P, PB-RP. (5) Two samples were judged to be at the /6 level of saturation: YR-GY, G-B. (6) Two samples appeared to be at level /4: BG-GY, PB-BG. (7) Only one sample appeared to be at level /4: BG-GY, PB-BG. (8) Only one sample appeared to be at the lowest saturation level of /2: GY-BG.

In the comparison of the cotton textured samples to the control samples of the same color combinations, the following was observed. (1) The saturation level of twelve of the cotton textured samples was similar to the saturation level of the control samples. They were samples: PB-BG, R-P, YR-RP, YR-GY, Y-R, Y-G, G-Y, B-G, RP-PB, GY-BG, BG-PB, and RP-YR. (2) Only one cotton textured sample appeared notably brighter

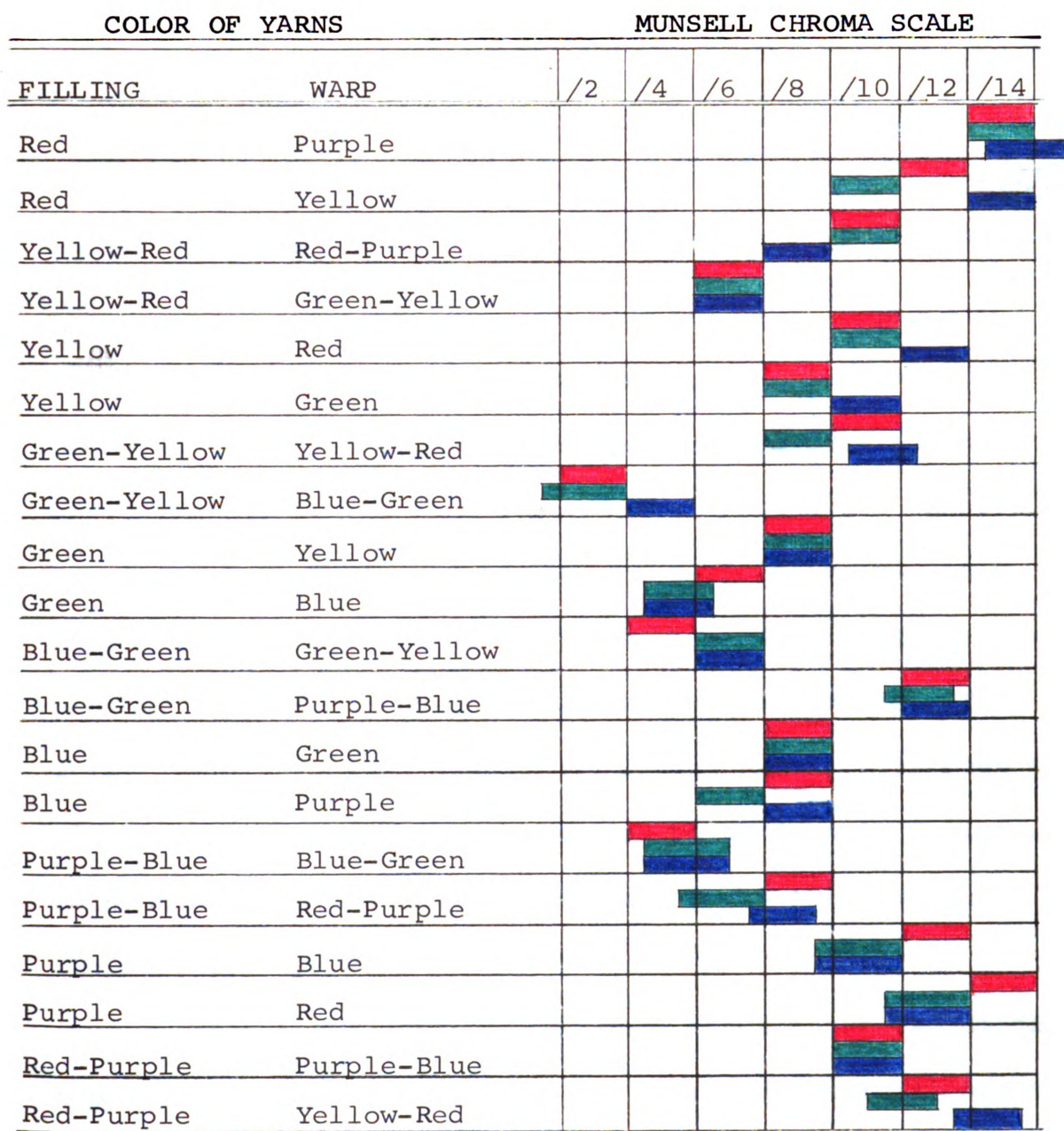


FIGURE 7

SATURATION RATING OF THE CONTROL SAMPLES IN ADDITIVE
 COLOR MIXTURE WHEN THE WARP AND FILLING YARNS
 WERE TWO STEPS APART ON THE COLOR WHEEL, AND
 THE DIRECTION OF CHANGE OF SAMPLES OF
 THE SAME COLORS WHEN TWO DIFFERENT
 TEXTURED YARNS WERE ADDED

Control yarn samples, plain mercerized yarns: 
 Cotton textured samples, cotton mat ratiné yarns: 
 Rayon textured samples, rayon sheen ratiné yarns: 

in saturation than its control sample of the same color: BG-GY.

(3) Seven of the cotton textured samples were rated duller in saturation than the control samples: R-Y, GY-YR, G-B, B-P, PB-RP, P-B, P-R.

When the rayon textured samples were compared to the control samples of the same colors, the following was observed: (1) Ten of the rayon textured samples appeared approximately at the same saturation level as the control samples: R-P, GY-BG, PB-BG, YR-GY, G-Y, BG-PB, B-G, B-P, RP-PB, PB-RP. (2) Six of the rayon textured samples appeared notably brighter in color than the control samples. They were: R-Y, Y-R, Y-G, GY-BG, BG-GY, and RP-YR. (3) Four of the rayon textured samples appeared to be notably duller in saturation than the control samples of the same colors: YR-RP, B-G, P-B, P-R.

When the comparison was made between the two different types of textured samples, it was observed that: (1) About ten of the rayon textured samples appeared approximately the same in saturation level as the cotton textured samples: YR-GY, G-Y, G-B, BG-GY, BG-PB, B-G, PB-BG, P-B, P-R, RP-PB. (2) Nine of the rayon textured samples appeared brighter than the cotton textured samples: R-P, R-Y, Y-R, Y-G, GY-YR, GY-BG, B-P, PB-RP, RP-YR. (3) Only one cotton textured sample appeared to be brighter than the rayon textured samples: YR-RP.

Summary on the saturation graph data. In summarizing the data on saturation of these samples, it was found that they ranged from the dullest saturation level of /2, to the brightest saturation level of 14/ on the Munsell chroma scale. Most of the samples appeared to be at the saturation level of /8, /10, and /12.

Samples containing red, red-purple and purple tended to show a high level of saturation while those containing purple-blue, blue, and blue-green tended to be at a lower saturation level. All three groups of samples did not vary extremely from each other in the same color combinations. Twelve of the cotton textured samples appeared to be at about the same saturation level as the control samples. Seven of the cotton textured samples appeared to be duller in saturation level and one brighter than the control.

In the rayon textured samples, eleven samples approximated the saturation level of the control samples. Five samples appeared brighter and four duller than the control samples.

When the two textured yarn samples were compared together, the following was observed. Ten of the samples had the same saturation level. Nine of the rayon textured samples tended to be brighter than the cotton textured samples. The cotton textured yarn seemed to appear brighter than the rayon sample of the same color in only one instance.

Conclusions at this point. Through the analysis of these samples, the following was concluded on the subject of saturation in samples in which the additive mixture of colors are colors two steps apart on the Munsell color wheel. It appeared that texture can, to some extent, change the saturation level of additive color mixture in fabric. After studying the information for these samples given above, it was observed that cotton textured yarns, such as those used in this study, generally caused the sample to appear the same in saturation, or duller in saturation than the control sample. This could be due to the mercerized yarns in the control samples.

The rayon textured samples, in more than half the cases, appeared at the same saturation level as the control samples. Of the rest of the rayon textured samples, four appeared duller, and five brighter than the control.

When the two different types of textured yarn samples were compared with each other, the rayon textured yarn samples appeared the same or brighter than the cotton textured samples of the same colors. None of the cotton textured samples appeared brighter than the rayon textured samples.

CHAPTER V

SUMMARY

This research was designed to study the effect textured yarns had on additive color mixture in hand woven fabric. A control group of samples, and two different types of textured yarn groups of samples were woven for comparison. The two types of textured yarn samples, a cotton mat, non-sheen texture and a rayon sheen texture, were compared to the control samples of the same color combinations. The similarities and differences of the samples in the attributes of hue, value and saturation, were observed by three judges and recorded. The information from the judging sheets was divided into twenty tables called series A and series B.

A general summary of the study will be given in this chapter. For the comparison and analysis of the samples, groups were chosen and closely analyzed, and generalizations were made. A summary of the two groups will be compared to each other and to the findings in the review of literature.

I. SAMPLES TO BE COMPARED AND METHOD OF COMPARISON

Choice of Samples for Analysis

For the comparison and analysis of the samples in this study, certain particular groups of samples were selected.

This study analyzed samples in which the warp and filling yarns were: (1) of complementary colors, and (2) colors two steps apart on the Munsell color wheel.

Tables Used for the Study

Excerpts of data from tables series A and B pertaining to the two groups under study were compiled into tables labeled series C. Table C-I was for samples of complementary colors, and Tables C-II-a and C-II-b were for samples in which the colors were two steps apart on the Munsell color wheel.

Graphs Used for the Study

Because of the apparent difficulty in analyzing all the data on the tables, three graphs were developed for each table in series C. This was to help in further understanding the findings in this study. One graph showed hue changes, one value changes and the other saturation changes. The analysis of the samples was made from the study of these graphs.

Graph on hue. The graph on hue change was studied and the direction on the color wheel of hue change of each sample was noted in the control samples and the two different textured yarn groups of samples. Each group of samples was categorized into three divisions:

- (1) Samples which favored the color of the warp yarns;

- (2) samples which approximated a color on the color wheel equidistant between the warp and filling yarn colors;
- (3) colors which favored the color of the filling yarn colors.

The direction on the color wheel the hue of the textured yarn samples favored was compared to the direction the hue of the control samples favored. Then the hue of the rayon textured samples exhibiting sheen, was compared to the cotton textured samples which did not exhibit sheen.

These groups were analyzed and generalizations were made.

Graph on value. The graphs on value change were studied by first noting the Munsell value notation of each control sample. These control samples were then put into groups according to their Munsell value notation. The cotton textured samples and the rayon textured samples were analyzed with respect to how they differed from the control samples of the same colors. Textured samples, having the same value as the control samples, were grouped together. Samples having a lighter value or a darker value than the control samples of the same colors were also put into groups. These groups were then analyzed and generalizations made.

The rayon textured samples were compared to the cotton textured samples of the same color combinations, and were analyzed in the same manner as the group above.

Graph on saturation. The information taken from the graphs on saturation change was recorded in much the same way as the information on value. First, the control samples were divided into groups according to their saturation level. Then the two types of textured yarn samples were divided into three groups: (1) those having the same saturation level; (2) those having a more intense saturation level; and (3) those having a duller saturation level than the control samples of the same colors. These groups were analyzed and generalizations made.

The two different types of textured samples were then compared to each other in the same manner as the three groups mentioned above.

II. THE EFFECT OF TEXTURE ON ADDITIVE COLOR MIXTURE

The main questions with which this report concerned itself were: (1) Does texture effect additive color mixture in fabric? (2) How does the effect of the rayon texture differ from the cotton texture? (3) How did the findings in this report compare to those found in the review of literature?

These questions will be answered in three ways, in each of the three attributes of color; hue, value and saturation. (1) The information observed in the two different groups of samples studied will be compared. (2) The information

on the two different types of textured yarns will be compared, and (3) the general observations will be compared to those found in the review of literature.

Hue

The additive color mixture obtained in the two groups of samples under study.

Complementary color combinations. The additive color mixture obtained in the group of samples of complementary color combinations mostly blended to a hue which very closely approximated gray.

This result of gray was the expectant outcome of complementaries in additive color mixture.

Combinations of two color steps apart on the Munsell color wheel. In the group of samples in which the warp and filling yarns were two color steps apart on the Munsell color wheel, most of the samples blended to a color equidistant between the warp and filling yarn colors. The others blended to a color somewhere on the color line between the warp and filling yarn colors.

Comparing the two groups of samples. The following was observed in the samples of both groups studied for this report. Both types of textured yarn samples in the group of complementary colors and colors two steps apart on the color

wheel had the same effect on hue in additive color mixture in fabric. They caused the hue of the samples to slightly favor the hue of the texture, whereas in the control samples the hue generally favored the hue that would result from an equal blending of the two colors, or a hue which slightly favored the warp yarn hue.

Generalization on the effect of texture on hue in additive color mixture. Therefore, the generalization could be made that both rayon and cotton textured yarns changed the color of hue of additive color mixture in fabric to favor the hue of the textured yarns. Some yarns altered the hue to a greater or lesser degree than others.

Comparison to the review of literature. A comparison of this information cannot be made to the review of literature as there was no information available on the effect of texture on the hue of additive color mixture.

Value

It was found that texture affected the value in fabric of additive color mixture. First the value ratings of the two groups of samples under study will be given, then comparisons and generalizations.

Value range of the group of complementary colors. The range of values for complementary color combinations in

additive color mixture was from a darkness of value 3/ to a lightness of value 7/ on the Munsell value scale.

Value range of the group two color steps apart on the Munsell color wheel. The value range for this group of samples was from a low of 3/ to a high of 8/ on the Munsell value scale. Most of the samples rated value 4/, 6/, and 7/.

The effect of texture on value in additive color mixture in fabric. It was observed that both types of textured samples, in both groups under study, had samples that appeared lighter than, the same as, and darker in value than the control samples of the same color combinations.

In a closer analysis, it was seen that when the color of the textured yarn was light in value, the samples appeared lighter than the control samples. In samples in which the color of the textured yarns were dark in value, the textured samples appeared darker in value than the control samples.

Generalization on the effect of texture on value in additive color mixture. Therefore, the generalization could be made that the value of the textured samples stayed the same as the control samples, or favored the value of the color of the textured yarn.

The review of literature compared to these findings. Since it was not possible to find any information in the review

of literature as to the effect of texture on the value of additive color mixture, no reference could be made in support of this statement.

Comparing the two groups of samples under study. In comparing the complementary color combinations to the colors two steps apart on the color wheel, it was observed that the complementary colors had a greater percentage that were lighter or darker in value than the control samples. The colors two steps apart on the color wheel appeared to have a greater percentage of samples that were the same value as the control samples.

Comparing the two different types of textured yarns. In comparing the cotton textured yarn samples to those containing the rayon textured yarns, the following was observed. Nearly half of the samples in both groups studied appeared to be about the same value as the control sample. Of the other half, a greater part of the rayon textured samples appeared lighter than the control samples, whereas a greater part of the cotton textured samples appeared darker in value than the control samples.

The review of literature findings compared to the findings of this study as to the difference in the effect of the two kinds of textured yarns. The finding of this study

agreed in part with the information reported in the review of literature on the effect sheen and non-sheen texture had on the value level of colored fabric. However, since the color of the samples in this study were of an additive color mixture type, there was the added problem of the difference in value of the warp and filling yarns. This added factor was not considered in the discussion found in the review of literature.

Concerning the factor of value, the review of literature stated that fibers with a smooth unicellular construction, similar to the rayon used in the samples, has great luster and high light reflectancy and would appear lighter in value. Yarns in which the fibers were intermingled, roughly carded and had a down surface, like the cotton textured yarn used, produced very little luster and were apt to be less light in value.

Generalization on the effect of the two different types of textured yarns on value in additive color mixture. Therefore, the generalization could be made that texture does effect the value of additive color mixture in fabric. Rayon texture caused the fabric to be the same or lighter in value than the fabric without texture such as the control sample fabric; whereas, cotton mat texture caused the value to be the same or darker in value than the control samples.

Saturation

It was found that texture affected the saturation in fabric of additive color mixture. First the saturation ratings of the two groups of samples under study will be given, then comparisons and generalizations.

Saturation range of the group of complementary colors.

The saturation range of the group of samples of complementary colors was from the very dullest level of /2, to the brightest saturation level of /10 on the Munsell chroma scale. Most of the samples were in the lower ranges from /2 to /4. This indicated that the colors somewhat closely approximated gray.

Saturation range of the group of samples two color steps apart on the Munsell color wheel. The saturation range of the group two color steps apart on the Munsell color wheel ranged from the very dullest level of /2 to the brightest saturation level of /14 on the Munsell chroma scale. Most of the samples appeared to be at the saturation levels of /8, /10 and /12.

Comparing the two different groups under study. It was observed that both types of textured samples in both groups under study had samples that were brighter, the same as or duller in saturation than the control samples of the same color combinations.

In comparing the complementary color harmonies with those colors two steps apart on the color wheel, no noticeable differences were observed in the saturation rating of both of these groups of samples due to the introduction of textures.

Comparing the two different types of textured yarns.

In comparing the two types of textured yarns to the control samples, it was observed that the majority of the samples in each type of texture was the same in saturation as the control samples. Of the rest of the samples, the cotton textured samples appeared to have more examples that were less saturated than the control samples; whereas, the rayon textured samples had more examples that were brighter than the control samples.

Comparing the findings to the review of literature.

This finding agreed in part with the information reported in the review of literature on the effect sheen and non-sheen texture has on saturation in the color of fabric.

In the review of literature it was found that fibers with a high reflectance tended to be brighter; whereas, those with a low reflectance tended to be duller.

Generalization made on the effect of texture on saturation in additive color mixture in fabric. Therefore, the generalization could be made that texture does tend to slightly effect the saturation level of additive color mixture

in fabric. When change was apparent, the rayon texture tended to appear brighter and the cotton texture tended to be duller than the control samples of the same color combinations.

III. FUTURE STUDY ON THIS SUBJECT

This study has tried to closely analyze one aspect of color in the samples woven for this study. Because of the many different phases of color, and the tremendous interest in color in so many different fields of study, there are many other very interesting aspects of the samples that would be of value to study.

It would be interesting to discover if a change in weave, such as the twill weave woven in half of each of the samples, would change the effect of color of the samples.

It would be interesting to analyze more of the samples and make more detailed comparisons. Such as comparing two groups which are very close, like the analogous and colors two steps apart on the color wheel. This report compared the effect of texture on additive color mixture in fabric as to hue, value and saturation.

However, it would be interesting to compare the changes in color in hue, value, and saturation in just the different groups of control samples such as complementary, and analogous. This would be studying the changes in color itself rather

than the effect of texture on color.

Another interesting and challenging area of study would be to make a comparative study between the human eye judgment method and the mechanical methods for judging differences in color caused by texture.

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E. PERSONAL INTERVIEWS

Smith, Daniel. Research scientist at the Interchemical Corporation, Color Center, 432 West 45th Street, New York, New York.

APPENDIX

INFORMATION ON THE JUDGES

- Judge I. Mrs. Gayle Fredrick McDonald, B.A. in Interior Design, the School of Home Economics at Michigan State University. She has worked with color and has studied Color Theory with Assistant Professor Mary L. Shipley at Michigan State University.
- Judge II. Miss Patricia Tavenner, B.A. in Art at Michigan State University. She has taught art and has been an Art Supervisor in the Royal Oak schools in Michigan. She has studied widely in the field of color.
- Judge III. Mrs. Gay Wright Vela, B.S. in Home Economics Teaching at Michigan State University. She has done much work in color and has studied Color Theory with Miss Mary L. Shipley, Assistant Professor at Michigan State University.

THESIS: THE EFFECT OF TEXTURE ON ADDITIVE COLOR MIXTURE IN
FABRIC

Gay Wright Vela

JUDGES NAME _____

DATE JUDGED _____

COLOR		PLAIN	COT.	RAY.	COLOR		PLAIN	COT.	RAY.
RED	H				RED	H			
	V					V			
	S					S			
YELLOW- RED	H				YELLOW- RED	H			
	V					V			
	S					S			
YELLOW	H				YELLOW	H			
	V					V			
	S					S			
GREEN- YELLOW	H				GREEN- YELLOW	H			
	V					V			
	S					S			
GREEN	H				GREEN	H			
	V					V			
	S					S			
BLUE- GREEN	H				BLUE- GREEN	H			
	V					V			
	S					S			
BLUE	H				BLUE	H			
	V					V			
	S					S			
PURPLE- BLUE	H				PURPLE- BLUE	H			
	V					V			
	S					S			
PURPLE	H				PURPLE	H			
	V					V			
	S					S			
RED- PURPLE	H				RED- PURPLE	H			
	V					V			
	S					S			

KEY

PLAIN = Control
COT. = Cotton Texture
RAY. = Rayon Texture
H = Hue
V = Value
S = Saturation

HOW TO MARK CHART

O = No Change
>R = Hue change toward Red
+ = Increase in value or saturation
- = Decrease in value or saturation

TABLE A-I

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

RED TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			SATUR.			HUE			VALUE			SATUR.		
FIL.-WRF.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
R - R	0	0	0	0	0	-	0	0	0	0	0	0	0	0	/	0	0	0
R - YR	-R	-R	0	-	-	-	-	-	0	-R	-R	-R	-	-	0	/	/	/
R - Y	-R	-R	-R	-	-	-	-	-	-	-R	-R	-R	0	0	0	/	/	/
R - GY	-R	-R	-R	-	-	/	0	0	0	-R	-R	-R	0	0	0	/	/	/
R - G	-GY	-GY	-GY	-	-	-	-	-	0	-GY	-GY	-GY	0	0	0	-	-	0
R - BG	-RP gray	-RP	-RP	-	-	-	/	/	/	-R	-10.R	-RP	/	/	/	/	/	/
R - B	-P	-7.5B	-P	-	-	-	0	0	/	-RP	-RP	-RP	/	/	/	/	/	/
R - PB	-RP	-RP	-RP	0	0	0	0	0	0	-RP	-RP	-RP	/	/	-	/	/	/
R - P	0	0	0	0	0	0	0	0	0	0	-R	0	0	0	0	/	0	/
R - RP	0	0	0	0	0	0	0	0	0	0	0	0	0	/	/	/	/	/

TABLE A-II

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

YELLOW-RED TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			INTENS			HUE			VALUE			INTENS		
FILL.-WRE	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
YR - R	0	-YR	-YR	0	-	-	-	-	-	0	0	0	0	0	0	0	0	-
YR - YR	0	0	0	0	0	0	0	-	-	0	0	0	0	0	0	0	0	0
YR - Y	0	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0
YR - GY	0	0	0	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
YR - G	-Y	-Y	-Y	0	0	0	-	0	-	-Y	-Y	-Y	0	0	0	-	-	-
YR - BG	-YR	-YR	0	0	0	/	/	/	/	-YR	-YR	-YR	/	/	/	/	/	/
YR - B	5.0YR	-YR	-YR	0	0	0	0	-	0	5.0YR	-YR	-YR	/	/	0	/	0	/
YR - PE	-RP	-YR	-YR	0	0	0	0	-	0	-RP	-YR	-YR	/	/	0	/	-	/
YR - P	-RPF	-YR	0	0	0	-	0	-	-	-RPF	0	0	/	/	/	0	-	-
YR - RE	0	0	0	0	0	-	0	0	0	0	-Y sl.	0	/	/	/	-	-	0

TABLE A-III

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

YELLOW TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			INTENS			HUE			VALUE			INTENS		
	FIL.	WRP		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Y - R	-Y	-Y	-Y	/	0	/	0	0	0	-Y	-Y	-Y	/	/	/	/	/	/
Y - YR	0	-Y	-Y	0	0	/	/	0	0	-Y	-Y	-Y	/	/	/	/	/	/
Y - Y	0	0	0	0	0	/	0	0	0	0	0	0	/	/	/	/	/	/
Y - GY	0	-Y	-Y	0	0	0	0	/	/	0	-Y	-Y	0	0	0	/	/	/
Y - G	-GY	-Y	-Y	/	/	0	0	0	0	-GY	-Y	-Y	/	/	/	/	/	/
Y - BG	0	-Y	-GY	/	/	/	0	0	0	-GY	-Y	-GY	/	/	/	/	/	/
Y - B	-GY	-GY	-GY	/	/	0	0	0	/	-GY	-GY	-GY	/	/	/	/	/	/
Y - PB	-GY HB	-GY HB	-GY HB	0	/	0	0	-	/	-Y	-GY	-Y	/	/	0	/	-	/
Y - P	-Y gray	-Y gray	-Y gray	/	0	0	-	-	-	-Y gray	-Y gray	-Y gray	/	0	0	-	-	-
Y - RP	-YR	-YR	-YR	/	/	-	-	0	0	-YR	-YR	-Y	/	/	0	0	0	0

TABLE A-IV

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

GREEN-YELLOW TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			SATUR.			HUE			VALUE			SATUR.		
FIL:WRP	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
GY - R	-YR	-YR	-GY	0	/	0	-	-	-	-YR	-YR	-YR	/	/	/	0	/	0
GY - YR	-Y	-Y	-GY	0	0	-	0	-	-	-Y	-Y	-YR	/	/	/	0	/	0
GY - Y	0	0	0	0	0	0	0	/	/	0	0	0	0	0	0	/	/	/
GY - GY	0	-Y	-G	0	0	0	0	0	-	0	-Y	-Y	/	/	/	/	/	/
GY - G	-GY	-GY	-GY	/	/	0	0	0	0	-GY	-GY	-GY	/	/	/	/	/	/
GY - BG	-GY	-GY	-GY	/	/	-	0	0	-	-GY	-GY	-GY	/	/	/	/	/	/
GY - B	-GY	-GY	-G	/	/	/	0	-	0	-GY	-GY	-GY	/	/	/	/	/	/
GY - PB	-Y 5.0	-GY	-GY	/	/	0	-	-	0	-GY 2.5	-GY	-GY	/	/	/	-	-	/
GY - P	-GY 2.5	-Y	-GY	-	/	0	-	-	-	-GY	-Y	-GY	/	/	0	/	-	-
GY - RP	-Y 5.0	-Y	-GY	/	/	/	0	0	0	-Y 5.0	-Y	-GY	/	/	/	/	/	/

TABLE A-V

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

GREEN TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			SATUR.			HUE			VALUE			SATUR.		
FL:WRP.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
G - R	-YR	-YR	0	-	/	-	-	-	0	-YR	-YR	0	/	/	/	0	0	0
G - YR	-G	-G	-G	0	-	-	-	-	-	0	0	0	0	0	0	0	0	0
G - Y	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0
G - GY	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0
G - G	0	-GY sl.	0	0	0	-	0	-	0	0	-GY sl.	-GY	0	/	0	0	0	0
G - BG	-GY	-GY	0	0	/	-	0	0	-	-GY	-GY	0	/	/	-	0	0	-
G - B	-G	-G	-G	0	-	0	0	-	-	-G	-G	0	0	-	0	0	-	-
G - PB	-G	-G	-G	0	/	0	-	-	-	-G	-G	-G	0	/	0	-	-	-
G - P	-G	-G	-G	0	/	0	-	-	-	-RP	-G	-RP	0	0	0	-	-	-
G - RP	-G	-G	-GY	0	0	0	0	0	0	-GY	-GY	-G	0	0	0	0	0	0

TABLE A-VI

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

BLUE-GREEN TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			SATUR.			HUE			VALUE			SATUR.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
BG - R	0	gray -R d.d.	-R	-	-	-	-	0	0	-BG	0	-BG	-	-	-	-	-	0
BG - YR	-G	0 gray	0	-	-	-	-	0	0	-G gray	0	-G	-	-	-	-	-	0
BG - Y	-GY	-GY	-G	-	-	-	0	0	0	-GY 10.0	-GY	-G	-	-	0	0	/	/
BG - GY	-GY	-GY	-GY	-	-	-	/	/	/	-G	-G	-G	-	-	-	/	/	/
BG - G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BG - BG	0	0	0	0	0	/	0	/	0	0	0	0	0	0	/	/	/	0
						sl.									sl.	sl.	sl.	
BG - B	-BG	-BG	-BG	0	0	0	0	0	0	-BG sl.	-BG	-BG	0	0	0	0	/	0
																sl.		
BG - PB	-PB 5.0	0	0	-	-	-	-	0	0	-B	-BG	-BG	0	0	0	0	0	0
BG - P	0	0	0	-	-	-	0	0	0	-PB	-PB	-BG	0	0	0	-	-	-
BG - RF	0	0	0	-	-	-	0	-	-	-BG	-BG	-BG	-	-	0	-	-	-

TABLE A - VII

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

BLUE TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			SATUR.			HUE			VALUE			SATUR.		
FIL.-WRP.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
B - R	-RPP	-RPP	-RP	-	-	0 sl.	-	-	-	-PB	-RPP	-B	0	-	0 sl.	-	-	-
B - YR	0 gray	0 gray	0 gray	0	-	-	-	-	-	0 gray	0	0	0	-	-	-	-	-
B - Y	0	-G	-G	-	-	-	-	0	0	-G	-G	-G	-	-	-	-	0	0
B - GY	-BG	-BG	-BG	-	-	0	0	0	0	-BG	-BG	-BG	-	-	0	-	0	0
B - G	0	-BG	0	-	-	-	0	0	0	-BG	-BG	-BG	-	-	- sl.	0	0	0
B - BG	0	-PB sl.	0	0	-	- sl.	0	0	0	0	-B 7.5	-B sl.	0	-	0 sl.	0	0	0
B - B	0	0	0	0	0	0	-	-	-	0	0	0	0	0	0	-	-	-
B - PB	0	0	0	0	0	0	-	-	-	0	0	0	0	0	0	-	-	- sl. sl.
B - P	-PB	-PB	-PB	0	0	-	-	-	-	-PB	-PB	0	0	0	0	0	0	0
B - RP	0	-P sl.	-P sl.	0	0	0	-	-	-	0	-P sl.	-PB sl.	0	0	0	-	-	-

TABLE A-VIII

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

PURPLE TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			SATUR.			HUE			VALUE			SATUR.		
FIL-WRP	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
PB - R	→RPP RP 5.	→P	→PB	0	-	0	-	-	-	→RPP	→P	→PB	0	0	0	-	-	-
PB - YR	0 gray	→B	→PB	0	-	-	-	-	-	0	→B	→PB	/	-	-	-	-	0 d.d.
PB - Y	gray →GY 2.5PB	→B	→B	-	-	-	-	-	0	→GY	→B	→B	-	-	-	0	0	-
PB - GY	→B 5.0	→B	→B	-	-	-	0	0	/	→B 5.0	→B	→B	0	0	0	0	0	0
PB - G	→BG	→BG	→BG	0	-	0	0	0	0	→BG	0	→BG	0	0	0	0	0	0
PB - BG	0	0	0	0	0	0	0	/	0 sl.	0	0	0	0	0	/	/	0	0
PB - B	0	0	0	0	0	0	0	-	0 sl.	0	0	0	/	0	/	0	0	0
PB - PB	0	0	0	/	/	0	-	-	- sl. sl.	0	0	0	/	/	/	0	-	0
PB - P	→PB	→PB	→PB	-	/	0 sl.	0	-	0	→PB	→PB	→PB	0	/	0	/	-	0 sl.
PB - RP	→P 2.5	→P	→P 2.5	0	0	0	-	-	-	→P 7.5	→P	→PB	/	0	0	0	-	0

TABLE A-IX

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

PURPLE-BLUE TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			SATUR.			HUE			VALUE			SATUR.		
FIL. - WRP.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
P - R	-RP	-RP	-RP	0	0	0	-	-	-	-RP	-RP	-R	0	0	0	-	-	-
P - YR	0 gray	-RP	-RP	0	-	-	-	-	0	0	0	0	0	-	-	-	0	0
P - Y	-P gray	-P	-P	-	-	0	0	-	-	-P gray	-P	-P	0	-	0	0	0	0
P - GY	-P gray	-P gray	-P	-	-	-	-	0	0	-P gray	0	-P	0	0	0	-	0	0
P - G	-P gray	-P gray	-P gray	0	0	0	-	-	-	-P gray	-P gray	-P	0	0	0	-	-	-
P - BG	-P	-P	-P	0	0	0	0	0	0	-PB	-P	-P	0	0	0	0	-	0
P - B	-PB 10.0	-P	-P	/	0	0	-	-	-	-PB	-P	-P	0	0	0	-	-	-
P - PB	-P	-P	-P	/	/	/	-	-	-	-P	-P	-P	/	/	/	-	-	-
P - P	0	0	0	/	/	/	0	-	-	0	0	0	/	/	/	0	-	-
P - RP	-RP	0	0	0	0	0	-	-	-	-RP	0	0	0	0	0	-	-	-

TABLE A-X

EACH JUDGES DECISION AS TO HOW THE TEXTURED YARN
SAMPLES CHANGED FROM THE CONTROL SAMPLES
IN THE SAME YARN COLORS

RED-PURPLE TEXTURED FILLING YARNS

YARN COLORS	COTTON TEXTURED YARNS									RAYON TEXTURED YARNS								
	HUE			VALUE			SATUR.			HUE			VALUE			SATUR.		
FIL. WRP.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
RP - R	→R 2.5	→RRP	0	0	0	0	-	-	0	0	0	→RP	0	0	0	0	0	0
RP - YR	→R 10.	→R	→R	0	-	-	-	-	-	→R	→R	→R	-	-	-	0	/	/
				sl.									sl.					
RP - Y	→YR	→YR	→R	-	-	-	-	-	-	→YR	→YR	→R	-	-	-	0	0	/
RP - GY	→R	→R	→R	-	-	-	-	-	0	→R	→R	→R	-	-	-	0	0	/
RP - G	0 or R	→R	→RP	-	-	-	-	-	-	0 or R	→R	→R	0	-	-	-	-	-
				sl.														
RP - BG	→RP 7.5	→RP	→RP	-	-	-	0	0	0	→RP 7.5	→RP	→RP	0	-	-	0	0	0
RP - B	→P	→P	→RP	-	-	-	0	0	0	→P	→P	→RP	-	-	-	0	0	0
				sl.	sl.								sl.	sl.				
RP - PB	→RP	→P	→RP	0	0	0	0	0	0	→RP	→P	→RP	/	0	0	0	0	0
													sl.					
RP - P	→RP	→RP	→RP	0	0	0	0	0	0	→RP	→RP	→RP	0	0	0	0	0	/
RP - RP	0	0	0	0	0	0	0	0	0	0	0	→R	0	0	0	/	/	/

TABLE B-I

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

RED FILLING YARNS

COLOR OF YARNS FILLING - WARP	CONTROL SAMPLES			SUMMARY OF TEXTURED SAMPLES					
	PLAIN COTTON			COTTON TEXTURE			RAYON TEXTURE		
	HUE	V	S	HUE	V	S	HUE	V	S
R - R	5.0 R	5	12	0	0 -	0	0	0 /	0
R - YR	2.5 YR	6	14	-R 0	-	- 0	-R	- 0	/
R - Y	2.5 Y 10.0 YR	8	12	-R	-	-	-R	0	/
R - GY	10.0 Y	7	4	-R	- /	0	-R	0	/
R - G	10.0 GY	5	8	-GY	-	- 0	-GY	0	- 0
R - BG	7.5 RP gray	5	2	-RP 10. gray	-	/	-RP 10. gray	/	/
R - B	7.5 PB	4	4	-PB 7.5	- /	0	-RP	/	/
R - PB	5.0 P	4	10	-RP	0	0	-RP	/	/
R - P	5.0 RP	4	14	0	0 -	0	0 or -R	0	/
R - RP	2.5 R	4	10	0	0	0	0	/	/

TABLE B - II

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

YELLOW-RED FILLING YARNS

COLOR OF YARNS FILLING- WARP	CONTROL SAMPLES PLAIN COTTON			SUMMARY OF TEXTURED SAMPLES					
	HUE	V	S	COTTON TEXTURE			RAYON TEXTURE		
	HUE	V	S	HUE	V	S	HUE	V	S
YR - R	7.5 R	5	12	-YR 0	- 0	-	0	0	0
YR - YR	2.5 YR	7	10	0	0	- 0	0	0	0
YR - Y	10.0 YR	8	10	0	- 0	- 0	0	0	0
YR - GY	2.5 Y	7	6	0	-	0	0	0	0
YR - G	5.0 GY	6	8	-Y	0	- 0	-Y	0	-
YR - BG	7.5 BG	6	2	-YR 0	0 /	/	-YR	/	/
YR - B	2.5 PB d.d.	5	4	-YR-5.0 gray	0	0 -	-YR 5.0 gray	/	/
YR - PB	10.0 P	4	4	-YR -RP	0	0 -	-YR -RP	/	/
YR - P	5.0 RP	4	8	-YR -RPR 0	0 -	- 0	0 -RRP	/	- 0
YR - RP	10.0 R	4	10	0	0 -	0	0 Y	/	- 0

TABLE B - III

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

YELLOW FILLING YARNS

COLOR OF YARNS FILLING WARP	CONTROL SAMPLES			SUMMARY OF TEXTURED SAMPLES					
	PLAIN COTTON			COTTON TEXTURE			RAYON TEXTURE		
	HJE	V.	S.	HUE	V.	S.	HUE	V.	S.
Y - R	10.0 R	6	10	-Y	/ ₀	0	-Y	/	/
Y - YR	7.5 YR	8	10	-Y 0	0 /	0 /	-Y	/	/
Y - Y	7.5 Y	8	8	0	0 /	0	0	/	/
Y - GY	2.5 GY	7	4	-Y 0	0	/ ₀	-Y 0	0	/
Y - G	10.0 YG	6	8	-Y -GY	/ ₀	0	-Y -GY	/	/
Y - BG	10.0 YG	6	4	-O -Y -YG	/	0	-GY -Y	/	/
Y - B	2.5 BG	5	2	-GY	/ ₀	0 /	-GY	/	/
Y - PB	7.5 PB gray	5	4	gray -GY h.b.	0 /	0 /	gray -Y -GY	/ ₀	/ -
Y - P	10.0 P	5	4	-Y h.b.	0 /	-	-Y gray	0 /	-
Y - RP	10.0 R	5	4	-YR	/	0 -	-YR -Y	/ ₀	0

TABLE B-IV

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

GREEN-YELLOW FILLING YARNS

COLOR OF YARNS FILL. - WARP	CONTROL SAMPLE PLAIN COTTON			SUMMARY OF TEXTURED SAMPLES					
	HUE	V.	S.	HUE	V.	S.	HUE	V.	S.
GY - R	7.5 R	5	8	-YR -GY	0 /	-	-YR 7.5	/	0 /
GY - YR	2.5 YR	7	10	-Y -GY	0 -	- 0	-Y -YR	/	0 /
GY - Y	2.5 GY	8	6	0	0	/ 0	0	0	/
GY - GY	5.0 GY	7	4	0 -Y -G	0	0 -	-Y 0	/	/
GY - G	2.5 G	6	6	-GY	/	0 0	-GY	/	/
GY - BG	5.0 G	6	2	-GY	/	0 -	-GY	/	/
GY - B	2.5 B	5	4	-GY -G	/	0 -	-GY	/	/
GY - PB	5.0 PB	4	6	-GY -Y	/	- 0 0	-GY 2.5	/	- /
GY - P	7.5 P	4	4	br. -GY 2.5 -Y	- 0 /	-	br. -GY -Y	/	- 0 /
GY - RP	2.5 R	5	4	-Y 5.0	/	0	-Y 5.0 -GY	/	/

TABLE B-V

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

GREEN FILLING YARNS

COLOR OF YARNS FILLING--WARP	CONTROL SAMPLES			SUMMARY OF TEXTURED SAMPLES					
	PLAIN	COTTON		COTTON TEXTURE			RAYON TEXTURE		
	HUE	V.	S.	HUE	V.	S.	HUE	V.	S.
G - R	7.5 R	5	8	-YR 0	- /	- 0	-YR 0	/	0
G - YR	7.5 YR	7	8	-G	- 0	-	0	0	0
G - Y	5.0 GY	7	8	0	0 -	0	0	0	0
G - GY	10.0 GY	7	6	0	0 -	0	0	0	0
G - G	2.5 G	6	10	0 sl.-GY	0 -	0 -	sl. -GY 0	0 sl./	0
G - BG	2.5 BG	5	6	-GY 0	/	0 -	-GY 0	/	0 -
G - B	7.5 BG	4	6	-G sl.-	0 -	- 0	-G 0	0 sl.-	- 0
G - PB	7.5 B	4	6	-G	0 /	-	-G	0 /	-
G - P	10.0 PB	4	6	-G	0 /	-	d.d. -RP -G	0	-
G - RP	d.d. 2.5 RP	4	2	d.d. -G -GY	0	0	d.d. -GY -G	0	0

TABLE B-VI

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

BLUE-GREEN FILLING YARNS

COLOR OF YARNS FILLING - WARP	CONTROL SAMPLES PLAIN COTTON			SUMMARY OF TEXTURED SAMPLES					
	HUE	V.	S.	COTTON TEXTURE			RAYON TEXTURE		
				HUE	V.	S.	HUE	V.	S.
BG - R	d.d. 5.0 R	5	8	d.d. -R gray 0	-	0 -	d.d. -BG 0	-	- 0
BG - YR	5.0 YR	7	8	-0 gray -G	-	0 -	-G gray 0	-	- 0
BG - Y	10.0 Y	8	6	-GY -G	-	0	-GY 10. -G	-	/ 0
BG - GY	7.5 GY	7	4	-GY	-	/	-G	-	/
BG - G	5.0 G	5	8	0	0	0	0	0	0
BG - BG	2.5 B	5	4	0 sl./	0 sl./	0 sl./	0	0 sl./	/ sl 0
BG - B	7.5 B	4	6	-BG	0	0	-BG	0	0 /
BG - PB	7.5 PB	6	12	0 5.0 -PB	-	0 -	-BG	0	0
BG - P	5.0 P	4	8	0	-	0	-PB -BG	0	-
BG - RP	10.0 RP	4	4	0	-	- 0	-BG	- 0	-

TABLE B-VII

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

BLUE FILLING YARN SAMPLES

COLOR OF YARNS FILLING—WARP	CONTROL SAMPLES PLAIN COTTON			SUMMARY OF TEXTURED SAMPLES					
	HUE	V.	S.	COTTON TEXTURE			RAYON TEXTURE		
				HUE	V.	S.	HUE	V.	S.
B - R	10.0 RP	4	10	-RP 2.5	- 0	-	-B -PB -RP	0 sl.	-
B - YR	2.5 YR	7	10	0 gray	- 0	-	0 gray	- 0	-
B - Y	2.5 GY	8	6	-G 0	-	0	-G	-	0
B - GY	10.0 YG	7	4	-BG	- 0	0	-BG	- 0	0
B - G	5.0 G	5	8	0 -bg	-	0	-BG	-	0
B - BG	2.5 B	5	4	0 sl.-PB	- 0	0	-B-7.5.	0 -	0
B - B	10.0 B	4	10	0	0	-	0	0	-
B - PB	5.0 PB	4	12	0	0	-	0	0	-
B - P	2.5 P	4	8	-PB	0 /	-	-PB 0	0	0
B - RP	2.5 RP	4	4	-P sl. 0	0	-	-P sl. -PB -0	0	-

TABLE B-VIII

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

PURPLE-BLUE FILLING YARNS

COLOR OF YARNS FILLING - WARP	COTTON SAMPLES PLAIN COTTON			SUMMARY OF TEXTURED SAMPLES					
	HUE	V.	S.	COTTON TEXTURE			RAYON TEXTURE		
				HUE	V.	S.	HUE	V.	S.
PB - R	10.0 RP	4	12	→RP 5.0 →P →PB	0 - -	-	→RP 5.0 →P →PB	0 - -	-
PB - YR	2.5 YR	6	8	→B →PB 0 gray	- - 0	-	→PB →B 0 gray	d.d. - /	d.d. - 0
PB - Y	7.5 Y	d.d. 7	d.d. 4	→GY →PB →B gray	- - -	0	→GY →B →B gray	- - -	0 0 -
PB - GY	2.5 GY	6	2	→B 5.0	-	0 /	→B 5.0	0	0
PB - G	10.0 G	5	6	→BG	0 -	0	→BG 0	0	0
PB - BG	2.5 PB	4	4	0	0	0 sl. /	0	0 /	0 /
PB - B	2.5 PB	4	10	0	0	0 sl. -	0	0 /	0
PB - PB	7.5 PB	3	12	0	/	- 0	0	/	0 -
PB - P	2.5 P	3	10	→PB	-sl. 0 /	0 -	→PB	0 /	/
PB - RP	7.5 RP	3	8	→P 2.5	0	-	→P 7.5 →PB	0 /	0 -

TABLE B-IX

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

PURPLE FILLING YARNS

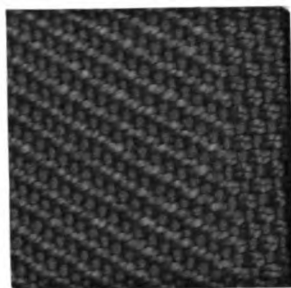
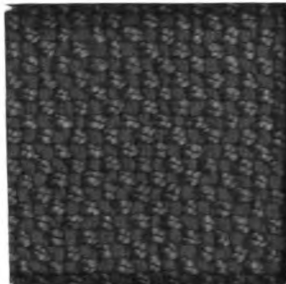
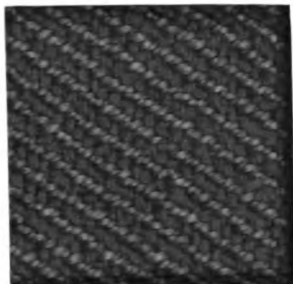
COLOR OF YARNS FILLING - WARP	CONTROL SAMPLES			SUMMARY OF TEXTURED SAMPLES					
	PLAIN COTTON			COTTON TEXTURE			RAYON TEXTURE		
	HUE	V.	S.	HUE	V.	S.	HUE	V.	S.
P - R	2.5 R	4	14	-RP	0	-	-RP -R	0	-
P - YR	10.0R	6	8	-RP gray 0	- 0	- 0	0	0 -	- 0
P - Y	2.5 Y	7	4	-P gray	- 0	- 0	-P gray	0 -	0
P - GY	10.0 Y gray	6	2	-P gray	-	0 -	-P gray 0	0	0 -
P - G	10.0 G	4	6	-P gray	0	-	-P gray	0	-
P - BG	7.5 PB	4	4	-P	0	0	-P -PB	0 sl.	0 -
P - B	5.0 PB	4	12	-P -PB	0 /	-	-P -PB	0	-
P - PB	7.5 PB 10.0 PB	3	12	-P	/	-	-P	/	-
P - P	5.0 P	3	10	0	/	- 0	0	/ sl.	- 0
P - RP	7.5 RP	3	10	0 -RP	0	-	0 -RP	0	-

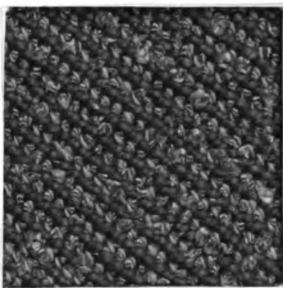
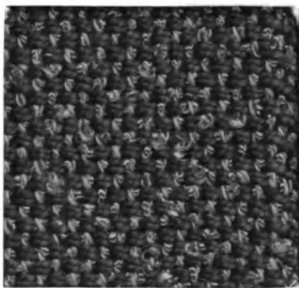
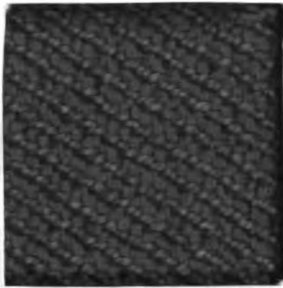
TABLE B-X

MUNSELL NOTATIONS GIVEN CONTROL SAMPLES AND A SUMMARY
OF CHANGES IN THE TEXTURED SAMPLES FROM THE
CONTROL SAMPLES IN THE SAME YARN COLORS

RED-PURPLE FILLING YARNS

COLOR OF YARNS FILLING - WARP	CONTROL SAMPLES			SUMMARY OF TEXTURED SAMPLES					
	PLAIN COTTON			COTTON TEXTURE			RAYON TEXTURE		
	HUE	V.	S.	HUE	V.	S.	HUE	V	S.
RP - R	5.0 R	5	14	-R 2.5 0	0	- 0	0 -RP	0	0
RP - YR	2.5 YR	6	12	-R 10.0	- 0	- sl.	-R sl.	- sl.	/ 0
RP - Y	5.0 Y	8	6	-YR -R	-	-	-YR -R	-	0 /
RP - GY	10.0 Y	7	4	-R	-	- 0	-R	-	0 /
RP - G	2.5 G	5	6	0 OF R -R -RP	- sl.	-	-R	- 0	-
RP - BG	7.5 B	5	2	-RP 7.5	-	0	-RP 7.5	- 0	0
RP - B	2.5 PB	5	6	-P -RP	- sl.	0	-P -RP	- sl.	0
RP - PB	10.0 PB	3	10	-RP -P	0	0	-RP -P	0 sl.	0 /
RP - P	7.5 P	4	10	-RP	0	0	-RP	0	0 /
RP - RP	10.0 RP	4	8	0	0	0	0 -R	0	/





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~~AUG 25 1965~~ 58

~~AUG 25 65~~

~~NOV 4 1968~~

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~~APR 2 1967~~

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~~MAR 29 1970~~ 183

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~~Q 332~~

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