A TECHNIQUE FOR DEVELOPING INTERIOR COLOR SCHEMES
BASED ON THE ADDITIVE AND SUBTRACTIVE
PRINCIPLES OF COLOR-MIXING

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CHAPTER I

INTRODUCTION

As the pace of human activity quickens and civilization becomes more complex, the significance of the environment becomes ever more apparent. An important environmental factor which is influential in human life is color. In the fields of study of psychology, physiology, and psychiatry, scientists in recent years have noted many consistent facts about human reaction to color and the affective power of color environment (2, p. 108).

Concern for the quality of the environment inside buildings is not new. It has always been regarded as of the utmost importance (6, p. 101). Today's interior designer has as his central concern the problem of organizing interior space so as to utilize this space both functionally and aesthetically. The designer not only arranges the furnishings into functional interior groupings, but also controls the affective mood of the interior through his choice of colors.

An examination of the history of color usage reveals that the use of color in architecture and decoration was once symbolic. Before the Renaissance an elaborate ritualism in the use of color was followed. This ritualism had to do
with religion, astrology, mythology, the planets, the points of the compass, and other such involvements (2, p. 2). As the Renaissance progressed into the fourteenth and fifteenth centuries, spiritual and emotional qualities governing color choice became apparent. It was not until then that these qualities were pursued and the artist was freed to convey his "feelings" without reference to symbolic conventions and traditions (2, p. 2).

Today color choices are based upon human needs, desires, and social values. These values contribute not only to man's pleasure, but also to his efficiency, comfort, and well-being. Mere color becomes "functional" color.

Functional color may be defined as a system or method of color application in which definite objectives are set up and in which results are determined by measurement (2, pp. 2-3).

The first step in the evolution of a practical color chart was begun by Sir Isaac Newton in 1666. He believed that there was a possibility of separating light into its component frequencies. Figure 1 illustrates how Newton

![Diagram of Newton's experiment with light and a glass prism.](https://via.placeholder.com/150)

*Fig. 1—Newton's experiment with light and a glass prism.*
projected a narrow beam of light through a glass prism onto a white surface (f, p. 2).

Instead of a white circle, there appeared a rainbow of colors elongated into an elliptical type figure (3, p. 14). Newton wrote:

The Spectrum did appear tinged with this Series of Colours, violet, indigo, blue, green, yellow, orange, red, together with all their intermediate Degrees in a continual Succession perpetually varying. So that there appeared as many Degrees of Colours, as there were sorts of Rays differing in Refrangibility (7, p. 1).

Newton goes on to explain that he "divided the colors into seven" because of his belief in the mystic properties of the number seven, but most observers see six at normal intensities and as few as three if the intensity is low (4, p. 107).

Newton continued his experiments with light and prisms. He further showed that if white light, which had been spread out through one prism according to its constituent wavelengths into a spectrum, be recombined again through a second prism so that all the rays were superimposed, white light was once more produced (3, p. 15). This process is termed additive mixing. The adding of the colors takes place in the mind of the observer and must, therefore, be a physiological or psychological effect (1, p. 105).

Figure 2 illustrates the additive primaries in relation to the subtractive primaries, to be discussed later. The primary colors for additive mixing are orange, green, and
violet, commonly known as red, green, and blue. Mixtures of orange and green give yellow, mixtures of green and violet give cyan, and mixtures of violet and orange give magentas (1, pp. 11, 105).

![Additive Colors](image1)

![Subtractive Colors](image2)

Fig. 2—Additive and subtractive primary and secondary colors.

It will be noticed that the secondary colors resulting from the various mixtures of the additive primary colors are the same as the primary colors of the subtractive system. This difference in the primary colors of the two systems is the basic difference between the additive principle of color-mixing and the subtractive principle of color-mixing.

Subtractive mixing operates through the process of selective absorption in which a part of the light coming from a source is removed either by absorption or scattering (3, p. 107). That part of the visual spectrum which is not subtracted gets through and is seen by the eye as a color (4, p. 64). A paint film which is pigmented, thus, selectively absorbs certain colors while reflecting others. When
two pigments or colorants are mixed together each will subtract, or selectively absorb, a portion of the visible spectrum. This process is known as subtractive mixing. The most useful primaries for subtractive mixing are yellow, magenta, and cyan, commonly referred to as yellow, red, and blue. Green results from mixing yellow and cyan; violet results from mixing cyan and magenta; and orange results from mixing magenta and yellow. When the subtractive primaries are balanced in color and amount, the result of mixing all three together is to subtract all the light from the source, leaving black (1, p. 103).

The subtractive color-mixing principle applies only to the mixing of pigments and dyes and the overlapping of transparent films, while the additive color-mixing principle can apply, not only to the mixing of colored light beams, but also to the visual blending of the colors in pointillist paintings, color television broadcasting, and woven textile materials. When threads of various colors are woven into some sort of pattern, from a short distance the individual threads may be visible, but from a greater distance these threads become indistinguishable as individual threads as they visually blend into a mixed total sensation (4, p. 86).

Statement of the Problem and Its Objective

In working with color samples and color-mixing processes there is a tendency to assume that the principles employed in subtractive color-mixing are valid in working with all
aspects of color matching. Perhaps the reason for this as-
sumption results from the experiences that most interior
designers have in their art training with the color-mixing
of paint pigments. Most designers have not had the oppor-
tunity to produce handwoven fabrics; so, they have not ex-
perimented with the interaction that may be achieved through
weaving colored yarns together using the additive principle
of color-mixing.

In the interior design profession there is a need to
develop a technique of working with additive color mixtures
as exemplified in woven fabrics and a need to understand how
the two color-mixing techniques of addition and subtraction
relate to each other. The interior designer works with
fabrics just as much as he works with paint pigments; there-
fore, he must be thoroughly familiar with both types of
color-mixing in order to select appropriate color schemes
for room settings.

As its objective this study develops a *modus operandi*
for the interior designer who must understand and work with
both additively and subtractively mixed colors in construct-
ing interior color schemes. An important adjunct of this
objective is the development of a table for reference use by
the designer. This table is composed of predominant hues
from both additive and subtractive color-mixing principles
together with subordinant colors, also from both color-mix-
ing principles. From this table, the designer may select
his predominant color for an interior and related subordinant colors to fulfill the interior's color scheme.

The Scope of the Problem

Because the interior designer must be knowledgeable of the psychology of color in order to predict human reaction and involvement in environmental color, the emphasis of this study is placed on the "feeling" of color and the psychological moods which are sought by the designer rather than on exploring color usage as found in specific historical periods of style in design. This kind of awareness in the interior designer of the importance that color plays in man's everyday life may result in a more functional use of color.

The Method of Procedure

To investigate the differences between the additive color-mixing principle and the subtractive color-mixing principle as applied to materials which impart color to interiors, experimentally developed color-reference samples are produced for both principles of color-mixing. But it was first necessary to explore theories of color (Chapter II) in order to better understand how interior colors are seen by man and how they affect his visual senses. These theories involve the electromagnetic spectrum as a whole and more specifically the visible spectrum, source of the light rays which are seen by man. To understand how colors and objects are seen it is necessary to explain how the eye
mechanism records visual sensations and passes this information to the brain for interpretation.

Chapter III presents the color-reference samples prepared by means of both the additive color-mixing principle (Fig. 6) and the subtractive color-mixing principle (Fig. 7). The additive samples are composed of handwoven textiles using the primary colors of orange, green, and violet. Between each primary color sample there are eight color variations from one primary color to the next primary color. These variations are made up of specified percentages of the two colors of yarns so that there are gradual progressions from one primary to the next, producing the Ostwald hue circle arrangement described in the fourth chapter.

The subtractive color-reference samples match the additive samples in their progression and arrangement, but are composed of paint pigments (tempera compounds). The primary colors employed for subtractive mixing are yellow, magenta, and cyan.

Employing the color-reference samples, Chapter IV is involved with the selection of colors for interior color schemes according to the additive and subtractive color-mixing principles. To assist the designer to competently select colors for interiors, there is a discussion about color determinants: psychological, color quality, and architectural. Psychological determinants deal with the psychology of color and how humans react to color; color quality concerns
the values and intensities associated with color-mixing and how color value and intensity may be applied to interior color schemes; and architectural determinants list the three main functional areas of residences and explore how the uses of the areas influence color choices.

With these determinants in mind the interior designer may select his predominant color and related subordinant colors from Table II. The twenty-four hues compiled in the color-reference samples are listed in this table as to complementary colors, triagonal colors, and analogous colors, corresponding to the three types of color schemes which are presented in this chapter. Samples of color schemes for the functional areas in interiors are listed in this chapter as guides to the designer in choosing his color schemes.
CHAPTER BIBLIOGRAPHY


CHAPTER II
COLOR THEORY

For the interior designer to understand the phenomena involved with color-mixing principles, it is necessary first to investigate the theories of color. These theories concern color vision and light sources as applied to objects and stimuli and to the sensations which they create in the human eye mechanism.

Theories of Vision

Theories of color vision attempt to explain the phenomena of normal and abnormal color vision. The most basic experimental facts for which every theory of color vision must account are those referring to color matching, or the psychophysical aspects of color vision. Also every theory of color vision must account for the physiological aspects of color vision; that is, it must explain the action caused by the radiant energy absorbed within the receptors (cones and rods) of the retina and transferred into nerve impulses. Finally, every theory of color vision must account for the psychological aspects of color vision, the nerve activities in the cortex leading to color perception in the mind (6, p. 84).
The psychophysical aspect of color vision refers to the relation between the stimulus (object) and the mental response. The physiological aspect deals with the "color-frequency-code" of nerve impulses along the optic nerve from the eye to the brain. When the impulse arrives at the brain, the psychological aspect signals a "color sensation." The physical aspect of vision concerns the spectral intensity of the radiation, or the "spectral composition" as measured in wavelengths on the electromagnetic spectrum (8, pp. 9-10).

Thomas Young (1773-1829), physicist, mathematician, and Doctor of Medicine (2, pp. 86-87), was the first to advance a color theory. His theory states:

... that the human retina contains three varieties of cones: one variety for the perception of red, orange and yellow rays; another for the perception of yellow-green, green, and blue-green rays; and a third for the perception of blue-green, blue and violet rays; and further that these three kinds of cones, acting in conjunction with one another, enable us to perceive not only all the different colours which are in the spectrum, but also all the colours which are possessed by objects seen in everyday life (5, p. 109).

There are perhaps fifty or more different theories of color vision, but none of the theories developed so far has been accepted as completely adequate because none accounts accurately for all known psychophysical, physiological, and psychological aspects of color vision.

A more recent theory of color vision has been set forth by colorist Faber Birren. He claims that there are three
separate and distinct aspects: light, chemistry, and sensation, each with its own unique laws and phenomena (1, p. 84).

The chemistry of color vision includes pigments and compounds. There are three primary hues: red, yellow, and blue, which, when mixed together, give all the various other hues, such as red and yellow to give orange, yellow and blue to make green, and blue and red to form violet. These mixtures are subtractive, resulting in black when the three primary colors are combined (1, p. 84).

Birren's physics of color vision involves light. Here the three primary colors are red, green, and blue-violet. Hermann von Helmholtz first noted that light rays seem to travel in these three hues, and when combined: red and green light blend to give yellow; green and blue light to make a clear, light turquoise; and blue and red light to produce a magenta. Light mixtures are additive, with white the combination of all hues (1, p. 84).

The sensory aspect of color is visual and embraces physiology and psychology. The human eye distinguishes four primary hues: red, yellow, green, and blue. All are unique and bear no resemblance to each other, yet all the other hues seem to be blends of these four primaries (1, p. 84).

Light Sources

The human eye is sensitive to only a narrow band of electromagnetic radiation, known as the visible spectrum. This visible spectrum is what may be called the psychophysical
term "light." Radiation near the middle of the visible spectrum is most effective in producing the visual brightness response with its effectiveness decreasing toward the long and short wavelength limits (8, p. 13).

Light has been defined as the aspect of radiant energy of which the human observer is aware through the visual sensations that arise from the stimulation of the retina of the eye (8, p. 345). Scientists such as Planck, Bohr, and Einstein, have concluded that radiant energy (visible light and color) is generated through space in the form of electromagnetic energy, a substance turned to luminosity by heat or electricity radiating certain waves, depending on its composition. Also, the waves that a substance will let off when excited will be identical with those it will absorb when radiant energy falls upon it. Such energy, however, has a corpuscular structure as well. This means that it is a tangible substance, and that it actually "pushes" through space and its mass may be bent by the force of gravity (2, p. 173).

The complete spectrum of electromagnetic energy, as shown by Figure 3, contains sixty or seventy "octaves." It begins, at one end, with radio waves of exceedingly great wavelengths and proceeds through infra-red rays, visible light, ultra-violet (the wavelengths getting shorter) and reaches the other extreme in X-rays, gamma rays, and cosmic rays (1, p. 76).
All this energy travels at the same rate of speed, about one hundred eighty-six thousand miles per second, and differs in length of waves as measured from crest to crest (1, p. 76).

Radio rays, the longest of all electromagnetic waves, used for "wireless," high-power trans-oceanic communication, ship-to-shore calling, direction finding and the like, may measure several thousand feet from crest to crest. In the form of induction heat, long radio rays are employed in industry for instantaneously raising temperatures of metals to harden them (1, p. 77; 2, p. 174).

Next come the commercial broadcasting rays which "bounce" back from the ionosphere and travel completely around the earth (1, p. 77; 2, p. 174).

Following the commercial band is the so-called "short-wave band" used for certain distance radio broadcasting, for police, ship, amateur and government radio. Also, these waves are used in diathermy by clamping electrodes to parts of the body so that heat may be generated to relieve rheumatism, arthritis, and neuralgia (1, p. 77; 2, p. 174).

The next radio band includes frequency modulation (FM) radio, television and radar with their wavelengths getting
shorter and ranging from several meters to a fraction of a meter. These wavelengths, however, penetrate the ionosphere and are not reflected back. They follow a straight path and require rebroadcasting points, although they may be sent out in controlled directions (1, p. 77; 2, p. 174).

After the radio band come the long (invisible) infra-red waves which can penetrate distance and heavy atmosphere. Plates sensitive to infra-red rays are used to take photographs where human eyes have difficulty in seeing. Included in the infra-red band is radiant heat. Its energy is used for heating and drying purposes and is emitted by steam radiators, electric heaters, and infra-red lamps (1, p. 77; 2, p. 174).

The sun's spectrum extends from relatively long waves of infra-red light, through the entire range of visible light (red, orange, yellow, green, blue, and violet) and on into the shorter waves of ultra-violet light. The visible light rays measure about 1/33,000 inch at the red end of the visible spectrum and about 1/67,000 inch at the violet end. The longer ultra-violet waves produce fluorescence in many substances (1, p. 77; 2, p. 175).

The erythemal rays, the energy which produces sun tan and which is employed for synthetic production of Vitamin D, come next. Still shorter ultra-violet energy has bactericidal properties, and is used to destroy certain microorganisms
and to sterilize materials, water, and air (1, p. 78; 2, p. 175).

After the ultra-violet rays on up the electromagnetic spectrum are the X-rays, starting with Grenz rays, or soft X-rays, used therapeutically for many skin diseases. Their energy does not have much penetrating power (1, p. 78; 2, p. 175).

Next come the X-rays of higher voltage and shorter frequency, used for diagnostic purposes and for therapy in certain forms of cancer. Hard X-rays, following in order, are used medically for deep-seated afflictions, as well as to take radiographic pictures to detect flaws in metal. X-ray frequencies may measure 1/2,500,000 inch where high voltages are involved (1, p. 78; 2, p. 175).

The radium rays, discovered by Pierre and Marie Curie, used to cure many forms of cancer, come between the hard X-rays and the fission emanation toward the short-wave end of the electromagnetic spectrum. These waves are emitted from nuclear fission and associated with the atomic bomb and the bombardment of the atomic nucleus. Such energy is also rapidly finding its way into medicine (1, p. 78; 2, p. 175).

The last and shortest wavelengths are those of the cosmic rays, which have not been thoroughly investigated. These rays probably are produced beyond the earth's atmosphere and spread their waves throughout the universe (1, p. 78; 2, p. 175).
The Visible Spectrum

As shown by the electromagnetic spectrum, visible light is only one of the forms of radiant energy. Red, at one end of the spectrum, has the lowest frequency—number of vibrations per second—and the longest wavelength. The frequency increases through the spectrum, with violet, at the other end, having the highest frequency and the shortest wavelength (4, p. 319).

Figure 4 illustrates the breakdown of the wavelengths of the visible spectrum (5, p. 17; 1, pp. 76-77; 4, pp. 318-319).

<table>
<thead>
<tr>
<th>Color</th>
<th>Wavelength (μm)</th>
</tr>
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<tbody>
<tr>
<td>red</td>
<td>0.76</td>
</tr>
<tr>
<td>orange</td>
<td>0.63</td>
</tr>
<tr>
<td>yellow</td>
<td>0.53</td>
</tr>
<tr>
<td>green</td>
<td>0.53</td>
</tr>
<tr>
<td>blue</td>
<td>0.43</td>
</tr>
<tr>
<td>violet</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Fig. 4—The Visible Spectrum

The symbol "$\mu$" in the Greek alphabet corresponds to our letter "m." It is pronounced "mū" and is used in science to represent one-thousandth part of a millimeter; this is nearly equal to one-twenty-five-thousandth part of an inch (5, p. 16).

Newton showed that if white light, which has been spread out according to its wavelength into a spectrum, is recombined again so that all the rays are superimposed, then white light is once more produced (5, p. 19), another proof of the additive formula of mixing colors.
The most common ways in which colors are produced commercially are by dyes and pigments. Dyes produce colors by absorbing certain parts of the spectrum and transmitting the other parts; pigments produce colors by absorbing certain parts of the spectrum and diffusely reflecting the other parts (5, p. 23).

The color of the dye or pigment is complementary to the part of the spectrum which is absorbed (5, p. 23). A dye absorbing violet rays would be yellow; one absorbing green rays would be purple. Where almost all the spectrum is absorbed the color of the dye or pigment will be that of the unabsorbed part. A pigment which absorbs violet, blue, blue-green, green, and yellow rays, and reflects orange and red, would then be orange-red in color. Black surfaces hold all the light so they become warmer more quickly than white ones which reflect the light (7, p. 16).

Color also may be created by mechanical means other than pigments and dyes. Color may be seen where no pigment is present, such as in soap bubbles, oil films on water, sea shells, ceramic glazes, bird feathers, crystals, and gas. The opalescent colors of these things are the result of reflecting surfaces, which causes refraction or diffraction of the light rays (4, p. 322).
Composition of the Eye

Colors and light waves are appreciated by the human eye which, in many important respects, resembles a photographic camera. Both have a lens in front and a sensitive surface at the back on which the sharply focused images of outside objects are projected. Both are lined with black inside, so that light rays which are not required are absorbed and do not create a glare. Both have an iris diaphragm in front, so that the width of the beam passing through the lens can be adjusted (5, p. 89).

Near the fovea in the central area of the retina is a "blind spot," where the optic nerve of the eye connects. Although the eye sees nothing at this point, a person is seldom conscious of emptiness or blackness because the brain "fills in" with whatever happens to be in the surrounding area (2, pp. 9-10).

In viewing objects and colors there is a certain amount of retinal lag. In motion pictures each frame image lags and carries over into the next as if it were part of a continuous picture. When the eye scans space, it does so in skips and hops; otherwise vision would be blurred. Also in viewing colors, there is a tendency on the part of the eye to bring up afterimages of the complementary colors. Experiments indicate that afterimage effects take place in the brain rather than in the eye itself. Hypnotized subjects
"see" afterimages despite the fact that the retinas of their eyes were stimulated by suggestion only (2, pp. 10-11).

The eye, which receives the waves of light from luminous bodies or reflected from non-luminous ones, consists of four principal parts: the outer spherical part, the lens, the retina, and the optic nerve (3, p. 16). Figure 5 shows a cross section of the eye and its principal parts.

![Cross-section of the eye and its principal parts.](image)

The transparent cornea, shaped like a watch crystal, is the outer covering of the eyeball. Behind this, the iris, a ring-like structure which forms the pupil of the eye, regulates the amount of light entering the eye. The iris, in front of the lens, expands or contracts to regulate the size of the pupillary opening—wide in dim light, narrow in brilliant light. Behind the pupil is the lens, which accommodates for seeing objects near or far. The back covering of the eyeball is the retina, a network of sensitive nerve endings, where the light is focused and from
which impulses are transmitted to the brain by the optic nerve (1, p. 86; 3, pp. 16-17).

The retina, the light-sensitive expansion of the brain, has two types of photoreceptor cells: the rods—about one hundred thirty million in each eye—distributed evenly over the retina, and the cones—about seven million—more numerous in the central area and the fovea of the retina (1, p. 86).

It is now believed that the rods and cones are the immediate organs of vision: the rods, responding to very low rates of incidence of radiant energy (night vision), and the cones, responding to higher rates (day vision) and responsible for color vision (6, p. 85). Max Schultze in 1866 stated his "duplicity theory" that low-intensity vision is a function of the rods of the retina and high-intensity vision is a function of the cones. The rods react chiefly to brightness and motion in subdued light; the cones react to brightness and motion, and also to colors. In the central fovea and in the region next to it, most of the action of seeing takes place. Here the eye perceives fine detail and color. Foveal sight is essentially cone vision and day vision; peripheral sight is rod vision, especially useful at night (1, p. 86). Ordinarily, the smallest area of sensitivity to color is for green, then red, then yellow, and blue located in the small fovea area (2, p. 11).

The stimulation of color produces reactions throughout the human organism and the activity of one sense organ
influences other organs. Birren (2, p. 12) quotes Sherrington with

All parts of the nervous system are connected together and no part of it is probably ever capable of reaction without affecting and being affected by various other parts, and it is a system certainly never absolutely at rest.

Human vision has a bodily flow which rises and falls with the whole physiological rhythm of the body. Illness may affect visual acuity (the ability to recognize the precise structure of fine detail; 5, p. 101), and color perception. Extreme fear may impair sight, in whole or in part. Bright days will, through vision, effect a different attitude and even a different perception than dismal days. Man sees best when he feels his best, physically and mentally. To a large extent cheerful environment is conducive to soundness of body and mind (1, p. 92).

Vision is as much in the brain as it is in the eye. Stimuli received by the eye have no particular meaning until the brain interprets them. Seeing is not a matter of recording external stimuli alone, but of bringing forth mental recollections and experiences (1, pp. 89-90).
CHAPTER BIBLIOGRAPHY


CHAPTER III
COLOR-REFERENCE SAMPLES

When a person views an interior, his brain records the visual sensation through his eyes. The colors of the interior aid in interpreting what he sees by "known and accepted" color combinations previously recorded in his brain.

Interior color schemes have been developed over the years to provide pleasing and beneficial environments in which to work, play, worship, relax, and do other human activities. The interior designer chooses the color scheme which will best relate people to their surroundings so that they complement each other. For this reason, the designer must understand how the numerous colors found in an ensemble of furniture and accessories in an architectural setting interact when viewed collectively.

Seen together in such an interior grouping may be colors resulting from use of the two color-mixing principles. Additive (or optical) mixing occurs with the separate colors that constitute the textile materials used in the fabrication of the upholstery, drapery, and rug, while the paints and dyes applied to the walls, ceiling, and flooring are subtractively mixed. It is necessary for the interior designer to harmonize both additive and subtractive color-blends in order to achieve an appropriate color scheme.
Because of the dual relationship of the additively and subtractively mixed colors used in an interior, the designer must establish a basis for visually relating the two color-mixing principles. On such a basis of relationship rests the technique for developing interior color schemes which are constructed on the additive and subtractive principles of color-mixing.

To assist in the development of such color schemes, color-reference samples representing both systems of color-mixing are needed. These samples approximate materials which are used to impart color to an interior. The additive color-reference samples correspond to textiles which are used for draperies, upholstery materials, and rugs and carpets. The subtractive color-reference samples relate to pigments and dyes used for wall and ceiling paints and some types of flooring. With the relationships established between the additive and subtractive color-mixing principles the color-reference samples may be employed by the interior designer to construct harmonious color schemes.

Additive Color-Reference Samples

To establish the color-reference samples for additive color-mixing, colored yarns are woven together to represent interior fabrics. When two primary colors of yarns are woven together, they may be seen as a third, or intermediate color-blend. At close range, the yarns appear as two
distinct colors, but if viewed in a large expanse of material and at an extended distance, the two colors of yarns blend to produce the secondary hue. Thus, in viewing woven fabrics in an interior the observer’s eyes blend the colors of yarns additively, producing the secondary hue.

Preparation of Additive Samples

To demonstrate additive color-mixing as it might occur in some woven materials used in an interior, color-reference samples are woven of yarns using the three additive primary colors: orange, green, and violet. In preparing these samples, cotton carpet warp yarns are used both for the warp and weft threads. A sixteen dent reed, threaded two yarns per dent, gives an equal number of warp and weft threads in the samples. Plain weave, because it allows an equal warp and weft arrangement, is used. Table I shows the tie-up diagram or "draft" for the warp threads. The sequence of the treadling for inter-weaving of the weft threads follows the same draft as that of the warp tie-up.

Due to the limited size of these color-reference samples, it is helpful to employ the Maxwell disk (see Appendix) in optically blending the two colors of yarns. The secondary hues thus achieved by the rapid spinning of the motorized Maxwell disk may then be matched harmoniously to subtractively mixed colors.
### Table I

**Diagram of Draft for Woven Color-Reference Samples**

<table>
<thead>
<tr>
<th>Samples</th>
<th>1 2 3 4 5 6 7 8</th>
<th>9101 1213141516</th>
<th>1713192021222324</th>
<th>2526272829303132</th>
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</tr>
<tr>
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<td>xxxxxxx xxxxxxx</td>
<td>xxxxxxx xxxxxxx</td>
<td>xxxxxxx xxxxxxx</td>
<td>xxxxxxx xxxxxxx</td>
</tr>
<tr>
<td>12-x; 4-o samples 3, 11, 19</td>
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<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
</tr>
<tr>
<td>10-x; 6-o samples 4, 12, 20</td>
<td>xx xx xx xx xx</td>
<td>xx xx xx xx xx</td>
<td>xx xx xx xx xx</td>
<td>xx xx xx xx xx</td>
</tr>
<tr>
<td>8-x; 8-o samples 5, 13, 21</td>
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<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
</tr>
<tr>
<td>6-x; 10-o samples 6, 14, 22</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
</tr>
<tr>
<td>4-x; 12-o samples 7, 15, 23</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
</tr>
<tr>
<td>2-x; 14-o samples 8, 16, 24</td>
<td>xxx xxx xxx xxx</td>
<td>xxx xxx xxx xxx</td>
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</tr>
<tr>
<td>0-x; 16-o samples 9, 17, 1</td>
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<td>xxx xxx xxx xxx</td>
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<td>xxx xxx xxx xxx</td>
</tr>
</tbody>
</table>

Samples 1-9: "x" refers to orange; "o" refers to green
Samples 9-17: "x" refers to green; "o" refers to violet
Samples 17-24, 1: "x" refers to violet; "o" refers to orange
100% Orange
Sample #I-1

37.5% Orange; 12.5% Green
Sample #I-2

75% Orange; 25% Green
Sample #I-3

62.5% Orange; 37.5% Green
Sample #I-4

50% Orange; 50% Green
Sample #I-5
(Subtractive Primary—
Yellow)

37.5% Orange; 62.5% Green
Sample #I-6

25% Orange; 75% Green
Sample #I-7

12.5% Orange; 87.5% Green
Sample #I-8

100% Green
Sample #I-9

Fig. 6—Additive Color-Reference Samples
100% Green
Sample #1-9

37.5% Green; 12.5% Violet
Sample #1-10

75% Green; 25% Violet
Sample #1-11

62.5% Green; 37.5% Violet
Sample #1-12

50% Green; 50% Violet
Sample #1-13
(Subtractive Primary—Blue)

37.5% Green; 62.5% Violet
Sample #1-14

25% Green; 75% Violet
Sample #1-15

12.5% Green; 87.5% Violet
Sample #1-16

100% Violet
Sample #1-17

Fig. 6—Continued
100% Violet
Sample #1-17

87.5% Violet; 12.5% Orange
Sample #1-18

75% Violet; 25% Orange
Sample #1-19

62.5% Violet; 37.5% Orange
Sample #1-20

50% Violet; 50% Orange
Sample #1-21
(Subtractive Primary—Red)

37.5% Violet; 62.5% Orange
Sample #1-22

25% Violet; 75% Orange
Sample #1-23

12.5% Violet; 87.5% Orange
Sample #1-24

100% Orange
Sample #1-1

Fig. 6—Continued
Subtractive Color-Reference Samples

As a complement to the collection of additively-mixed color-reference samples of textiles, a comparative collection of subtractively-mixed color-reference samples of tempera compounds is prepared to represent the colors of paint pigments used in interiors.

Preparation of Subtractive Samples

The color-reference samples of paint pigments (tempera compounds) are prepared from the three subtractive primary colors magenta, yellow, and cyan. These colors are used in producing the intermediate hues between each pair of primary colors. In mixing the two pigments together for each sample, the lesser amount of the two colors is mixed into the larger amount, the reason being to change the most dominant color by the addition of the second color. For each gradation of color change an increased amount of the second color is used. If the two colors are mixed in equal proportions, then the lighter color is mixed into the darker color.

The term "parts" used to describe the mixtures of the subtractive color-reference samples, refers to a visual correspondence to the gradations of the additive color-reference samples. This is necessary because proportional changes in quantitative amounts of pigments added to the subtractively-mixed color-reference samples, do not produce the equal gradations found in the visually mixed additive color-reference samples.
4 parts Yellow; 4 parts Magenta
Sample #II-1
(Additive Primary--Orange)

5 parts Yellow; 3 parts Magenta
Sample #II-2

6 parts Yellow; 2 parts Magenta
Sample #II-3

7 parts Yellow; 1 part Magenta
Sample #II-4

8 parts Yellow
Sample #II-5

7 parts Yellow; 1 part Cyan
Sample #II-6

6 parts Yellow; 2 parts Cyan
Sample #II-7

5 parts Yellow; 3 parts Cyan
Sample #II-8

4 parts Yellow; 4 parts Cyan
Sample #II-9
(Additive Primary--Green)

Fig. 7--Subtractive Color-Reference Samples
<table>
<thead>
<tr>
<th>Sample #</th>
<th>Cyan : Yellow</th>
<th>Magenta</th>
</tr>
</thead>
<tbody>
<tr>
<td>#II-9</td>
<td>4 : 4</td>
<td></td>
</tr>
<tr>
<td>#II-10</td>
<td>5 : 3</td>
<td></td>
</tr>
<tr>
<td>#II-11</td>
<td>6 : 2</td>
<td></td>
</tr>
<tr>
<td>#II-12</td>
<td>7 : 1</td>
<td></td>
</tr>
<tr>
<td>#II-13</td>
<td>3 : 0</td>
<td></td>
</tr>
<tr>
<td>#II-14</td>
<td>7 : 1</td>
<td></td>
</tr>
<tr>
<td>#II-15</td>
<td>6 : 2</td>
<td></td>
</tr>
<tr>
<td>#II-16</td>
<td>5 : 3</td>
<td></td>
</tr>
<tr>
<td>#II-17</td>
<td>4 : 4</td>
<td></td>
</tr>
</tbody>
</table>

(Additive Primary--Green)

Fig. 7--Continued
4 parts Magenta; 4 parts Cyan
Sample #II-17
(Additive Primary--Violet)

5 parts Magenta; 3 parts Cyan
Sample #II-18

6 parts Magenta; 2 parts Cyan
Sample #II-19

7 parts Magenta; 1 part Cyan
Sample #II-20

8 parts Magenta
Sample #II-21

7 parts Magenta; 1 part Yellow
Sample #II-22

6 parts Magenta; 2 parts Yellow
Sample #II-23

5 parts Magenta; 3 parts Yellow
Sample #II-24

4 parts Magenta; 4 parts Yellow
Sample #II-1
(Additive Primary--Orange)

Fig. 7--Continued
Description of Color-Reference Samples

A collection of twenty-four color-reference samples prepared for this study represents the additively mixed colors. Included are the three additive primary hues, orange, green, and violet, and twenty-one intermediate hues. There are seven graduated hue changes between orange and green, seven between green and violet, and seven between violet and orange.

A similar collection of twenty-four color-reference samples represents the subtractively mixed colors. These are composed of the three subtractive primary hues, yellow, magenta, and cyan, and likewise have twenty-one intermediate hues with seven graduated hue changes between each pair of primaries, i.e., yellow and magenta, magenta and cyan, and cyan and yellow.

The color samples in each collection are identified by a numbering system constituted of a Roman numeral designating the color-mixing principle used to produce the sample, and an Arabic numeral designating the hue. The Roman numeral "I" indicates the color-reference sample is an additively mixed color, and "II" indicates the sample is a subtractively mixed color.

The first group of Arabic numbers, applicable to both color-mixing systems, begins with 1 (orange) and ranges to 9 (green). In additive mixing orange is a pure hue, but in subtractive mixing it is an equal mixture of yellow and
magenta. Likewise, the green in additive mixing is a pure hue but in subtractive mixing is an equal mixture of the subtractive colors yellow and cyan. The color sample 5, halfway between orange and green, is the yellow hue. In additive mixing yellow is an equal "percentage" mixture of orange and green, but in subtractive mixing yellow is a pure hue, or primary color. Between 1 (orange) and 5 (yellow) there are three gradations numbered 2, 3, 4 with colors gradating between orange and yellow. Between 5 (yellow) and 9 (green) there are three more gradations numbered 6, 7, and 8 with colors gradating between yellow and green.

Number 9, the green hue, begins the second group of Arabic numbers and colors, and gradates to 17, the violet hue. Green as explained above is a pure hue in additive mixing and an equal mixture in subtractive mixing. Violet in additive mixing is a pure primary hue and in subtractive mixing is an equal mixture of cyan and magenta. Number 13 (cyan) is the intermediate gradation between 9 (green) and 17 (violet). In additive mixing this is an equal "percentage" mixture of green and violet, but in subtractive mixing this is a pure primary hue. Between 9 and 13 there are three gradations numbered 10, 11, 12 with hues gradating between green and cyan. From 13 to 17 there are three more gradations numbered 14, 15, 16, with hues changing between cyan and violet.
The third group of Arabic numbers ranges from 17 (violet) to 24 and back to 1 (orange). Both of these colors have been explained as to their composition in the two color-mixing principles. Between violet and orange number 21 corresponds to the hue magenta. In additive mixing this is an equal "percentage" mixture of violet and orange, but a pure primary hue in subtractive mixing. Gradients numbered 19, 19, and 20 range between violet and magenta, and gradients numbered 22, 23, and 24 range between magenta and orange, the beginning of the hue circle.

In the additive color-reference samples the mixtures are described in terms of percentages of constituent primary colors, referring to the number of yarns of the specified colors. The pure hues are constituted of 100 per cent of one color of yarn. The second gradation from this pure hue is constituted of a percentage of 37.5 of the first color of yarn and 12.5 per cent of an added color of yarn. The third gradation is constituted of a percentage of 75 of the first color of yarn and 25 per cent of the added color of yarn. The fourth gradation is constituted of a percentage of 62.5 of the first color of yarn and 37.5 per cent of the added color of yarn. The fifth gradation is composed of an equal number of yarns of the two colors, being a 50 per cent mixture.

The sixth gradation is constituted of a percentage of 37.5 of the first color of yarn and 62.5 per cent of the
added color of yarn. The seventh gradation is a mixture of 25 per cent of the first color of yarn and 75 per cent of the added color of yarn. The eighth gradation is a mixture of 12.5 per cent of the first color of yarn and 87.5 per cent of the added color of yarn. The ninth gradation is the next pure hue color of yarn and the beginning of another group of gradations from one pure hue color of yarn to the next pure hue color of yarn, following the same percentages as listed above.

The subtractive color-reference samples are mixed from the subtractive primaries in such proportions as to correspond with the additive color-reference samples.
CHAPTER IV

TECHNIQUE OF DEVELOPING COLOR SCHEMES

Introduction

Color is a fact of nature. In nature, all colors ever known to man exist, and the myriad colors of nature are always a delight to man's eyes. But when man utilizes color for interiors, he may create something soothing, offensive, provocative, or harmonizing. If the colors are pleasing to his eyes, then he likes what he sees.

Color trends change from year to year as the tastes of the population change. Some trends are replaced as a reaction against a previous color phase which has become tiring or dated. As one color trend develops, the previous trend phases out. Before the advent of rapid communication, leisure travel, and higher incomes, there were regional color preferences in the United States. Urban populations in the northern and eastern sections preferred strong colors, while the residents of the sunny areas of the Pacific Coast region relied on pastels. Southerners liked deep red, and New Englanders favored tan and brown. Shades from red, through yellow, and on to green have been in favor in all areas at all times. Today, the modern architectural use of windows brings landscape colors into the interiors. Thus, color
trends today appear to be going toward the "earthy" colors. The selection and use of colors have become more utilitarian just as architecture has become more functional and less ornate in recent years.

Determinants of Color Schemes

Psychological Determinants

Before the importance of color had been realized, color selection was mostly a matter of "good taste." Today, this aspect is still important, but now the personalities of the occupants of interiors are also important factors in dealing with color selections. Environmental colors now provide psychological as well as aesthetic benefits for the occupants of the interiors.

The psychological effects provided by colors promote comfort and relaxation. Color schemes should complement the personalities and create psychological moods based on the habits and temperaments of the inhabitants. Colors may unify objects and elements into pleasing groupings. Interiors achieve "character" through the use of proper colors.

The interior designer must recognize the importance of matching colors to personalities. In this way, he may use the psychological "feeling" of colors to great advantage.

Various writers have attempted to match psychological associations to colors. The color associations described in the following paragraphs represent some of the associations...
attributed to the colors commonly used in interior color schemes.

Blue.--Truth is associated with blue as it represents the clear, transparent sky and heaven. It produces peace of mind, although a deep blue has mournful connotations associated with it (1, p. 97). Blue creates a formal atmosphere in an interior.

Green.--Another favorite interior color, green represents nature and eternity. It is quiet, refreshing, and peaceful (2, p. 178). Green is considered the most tranquil of all colors and is suitable for quiet areas in an interior (3, p. 108).

Violet.--The third cool interior color is violet. This is a regal color, representing sacrifice, perseverance, and composure. It gives a feeling of expensive taste since its use was confined to royalty in ages past (1, p. 98).

Yellow.--Another favorite predominant interior color, yellow is a warm color. This color is sunny and cheerful, having a feeling of high spirit and health. In commercial applications it means caution (2, p. 178).

Red.--A favorite accent color, red is the most exciting of all colors. The brilliant intensity of red produces a warm or hot feeling. There is also a passionate feeling of love associated with red, as this color stands for the
holidays of Christmas and Valentine's Day (2, p. 178; 1, pp. 96-97). Red also has a feeling of patriotism associated with it (3, p. 103).

Orange.—The bright, luminous color of orange gives off a warm feeling. As an accent color it is jovial, lively, energetic, yet forceful (2, p. 178).

White.—This color symbolizes purity and innocence. It gives spatial feeling to interiors that may be too small (1, p. 98; 2, p. 178).

Black.—As an opposite to white, black denotes death and silence. Normally it is not used in interiors except as an accent in contrast to other colors (1, p. 98).

Brown.—The many shades of brown, from tan to beige, represent the earth. Substantialness is a key word for brown (2, p. 188).

**Color Quality Determinants**

In addition to psychological requirements, there are also functional and visual aspects of color which determine color choices for interiors. Colors can lighten and brighten a dark room, or give intimacy to a large room.

The quality of color value may be equated with gravity. People's experiences with gravity indicate that heavier objects are usually closest to the earth, and as an object gets lighter, it rises from the earth. This law of gravity
holds true for color values, with dark colors having an attribution of "heaviness." In this context a color scheme might be prepared so that the darkest value would be the floor tone, the middle value the wall tone, and the lightest value the ceiling tone.

Color value may also be used in an interior to add emphasis. An intimate grouping may be created with a larger area. To attract attention to a wall, window, door, or bookcase, the wood trim may be darker in value than the floor and wall. To emphasize a functional grouping, the furniture may be of a lighter or darker color value than the surrounding wall or floor covering.

Using different color values within one color family can create a harmonious color scheme. In this way the colors relate in hue while letting one value dominate the other values. As an example, if a specific color of an oriental rug sets the color scheme, all colors used elsewhere in the interior should be of lighter value than the main theme color.

Color luminosity concerns the amount of light reflected by color. If the interior lacks sufficient daylight, bright colors should be selected to aid in reflecting what light there is available. Conversely, if the light is too distracting, then dark colors should be used to absorb light rays and help quieten the brilliance of the light.
Architectural Determinants

Functional areas and the physical features of the interior, such as windows, wall space, natural light, types of floors, and styles of furniture are the architectural determinants of color schemes. Large windows opening onto pleasing views may bring outdoor colors into the room; hence, a careful choice of interior colors related to landscape colors must be made. A large wall space, by its very size, will have a dominating effect on the interior because of its large expanse of color; so, this color must be chosen with care. Colors are dependent upon light. If natural light is present in abundance during the day, and artificial light in the evening, colors will change accordingly. Certain styles of furniture are enhanced with specific colors and made objectionable with other colors.

Another architectural determinant influencing color choice in an interior involves the partitioning of spaces into functional areas. These areas are determined as to their use by the occupants, and the colors that are selected for these areas must be related to the architectural arrangement of the interior. A residence may be divided into three main areas and several sub-areas.

Living Areas.—In a residence, the living section of the house is where the family meets friends, relaxes, dines, and entertains. (In a commercial building, this area
corresponds to the lobby, restaurant, and general meeting rooms.) The first impression of an interior is given by the living area, often referred to as the "show place of the home."

A well-designed living area is a functional, useful, and integral part of the home, and it will usually be the most handsomely decorated room. An effective use of color and lighting techniques, a tasteful selection of wall, ceiling, and floor covering materials, and a selection and placement of functional, well-designed furniture will provide an inviting appearance. The color, style, and materials should be selected to minimize faults and emphasize good points.

Blues and greens continue to be the most popular colors for use in living areas. These two color families are inviting, restful, and pleasant for the eyes. They are both cool colors, but through the use of complementary colors as accents, they can give a warm feeling.

Another area of the living section of the house is the dining area. In many homes this is just an extension of the living room, although it may be a separate room. The needs of the family determine the size and placement of the dining area. When the dining area is integrated with the remainder of the living area, the floor, wall, and ceiling treatments may either be the same as the living area or related to it through the use of a continuing predominant
Another way to relate the two areas is to reverse the color schemes, thereby making the predominant color in one area the subordinant color in the other area.

The third main area in the living group is the family room, or den. With more informal living and more leisure time, the growth and popularity of the family room has become universally accepted. In this multi-purpose activity room, the atmosphere is vibrant and exciting. By using two bold hues against each other with almost equal force, even a large room seems comfortable. For accent, a third color equally strong will give the room life.

**Sleeping Area**—The sleeping area, usually located in a quiet part of the house, should be planned to provide facilities for maximum comfort. Here, color is most important as it may provide a quiet, restful environment. Matching or contrasting bedspreads, draperies, and carpets help accent the restful, analogous color schemes, popular in bedrooms today. Naturally, the main piece of furniture in this area is the bed, and the color of its covering will usually set the main theme for the color scheme. Since the bedroom is of a more personal nature, individual taste may be indulged as long as the color choice does not conflict with the purpose of the area, which is sleeping.

Because of the importance of the bath area to the bedrooms, the bath is treated as an extension of the sleeping area. The bath should be designed to provide the maximum
amount of light and color. Fixtures and accessories may be designated to match or complement the color scheme. Also, counter tops and cabinets may be mixed or matched in color selection. Accent colors may be achieved in towels and accessories.

Service Areas.—The maintenance and service of the home center around the kitchen. With the great number of activities which take place in this area, it should be designed for the utmost efficiency. Some kitchens may also be used as dining areas, and even laundry areas. A family kitchen provides the meeting place for the entire family in addition to providing for the normal kitchen functions. Light is most important in the kitchen since this area is in use at all times of day. The colors chosen for the kitchen should give the area warmth and livability. A three-color color scheme gives the room variety plus balance and unity.

Construction of Color Schemes

In structuring a color scheme for any interior area, the designer chooses one color to be used as a predominant "theme" color throughout the areas comprising the entire structure. Using this one predominant color, several subordinant colors may be added to complete the color scheme in each individual area. The predominant color may be a subtractively-mixed color painted on the walls, ceilings, or floorings; or an additively-mixed color appearing in draperies, bedspreads, or floor coverings.
To the predominant color, subordinate colors are added according to one of several logical schemes. The three schematic applications as treated in this thesis involve choosing (1) colors which are complementary to the predominant color, (2) colors which form a triad with the predominant color, and (3) colors which are analogous to the predominant color. These terms, complementary, triad, and analogous, refer to the positions of colors relative to each other on the hue circle as shown in Figure 8. The hue circle used in this study is that one developed by Ostwald (4, p. 46) in which there are twenty-four colors equally spaced side-by-side to form a circle. The numbers on the hue circle in Figure 8 correspond to the color-reference samples of both additively-mixed textiles and subtractively-mixed paint pigments presented in Chapter III, and not to the Ostwald numbering system which begins with yellow as the first color. The colors in this study are arranged from the oranges to the yellows (#1-4), from the yellows to the greens (#4-8), from the greens to the blues (#8-12), from the blues to the violets (#12-16), from the violets to the reds (#16-20), and from the reds back to the oranges (#20-24, 1).

A complementary color scheme is constructed from contrasting hues located opposite each other on the hue circle. An example of a complementary interior color scheme would be one in which shades of green are used for the wall and
Ceiling paint and floor covering, and shades of red (the opposite to green on the hue circle) are used for the upholstery, draperies, and accent accessories.

Using an opposite hue in a complementary color scheme creates contrast between the predominant color and the subordinant color. The visual effect may be overpowering if the two main areas of the room, such as the walls and the carpet, are in direct color contrast of equal intensity. The colors of the large surfaces of the room should be the predominant color of the complementary color scheme and should be in the same hue family; the opposite hue, as a subordinant color, should be employed for the other furnishings, such as the upholsteries and draperies.
A second type of color scheme which may be applied to an interior is the type made up of a triad of colors. Color triads result when three hues are equidistantly spaced on the hue circle, forming an equilateral triangle with the predominant color. An example of a color triad in an interior color scheme would be one with the predominant color of yellow used for the walls and ceiling, and the subordinate colors of red and blue used for the floor covering, upholstery, and draperies. It must be remembered that these hues are not pure hue colors but rather shades and tints of the suggested colors.

A third type of color scheme may be constructed of analogous colors, that is, of several closely related colors on the hue circle. As an example of this type of color scheme, yellow may be chosen as the predominant color, with orange and red as subordinate colors, in order to transform a "cold" room into a "warm" interior. The designer may specify a yellow ceiling, yellow and orange striped wallpaper and matching draperies, a red and orange blend carpet, with accessories in pure tones of these three hues. To "cool" a "hot" room, the opposite colors from red, orange, and yellow might be used, such as green, blue, and violet.

By selecting proper subordinate colors for use with the predominant color, harmonious interior color schemes will be achieved. In his book, Basic Color, Jacobson lists the constituents of harmonious color combinations:
they reflect properly balanced amounts and varieties of chromatic light (complementary colors); they satisfy a need of rhythm (repetition of interval); they suggest a sense of form, of direction, or of space; they please us with their similarities (recognizable relationships); they surprise or stir us by their opposition (contrast); they arouse welcome memories (4, p. 58).

To aid the interior designer in constructing harmonious color combinations, the following table has been compiled, matching predominant colors to related subordinate colors. The numbers in the table refer to the color-reference samples for both systems of additive and subtractive color-mixing as presented in Chapter III. The related subordinate colors are divided into three categories of complementary, triagonal, and analogous colors which correspond to the three applications of color schemes described in the preceding text.

In reading this table, first a predominant color is selected; then subordinate colors are read across the table. As an example, if 1 (orange) is the predominant color, subordinate colors would be 13 (blue) as the complementary color, 9 (green) and 17 (violet) triagonal colors, and 23 (red-orange) to 3 (orange-yellow) analogous colors.

Examples of Applied Color Schemes

To illustrate how a designer might interpret Table II, the following examples of applied color schemes are presented. The choices of colors used in constructing these schemes
TABLE II
PREDOMINANT COLORS AND RELATED SUBORDINANT COLORS

<table>
<thead>
<tr>
<th>Predominant Colors</th>
<th>Subordinant Colors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complementary</td>
</tr>
<tr>
<td>1 (orange)</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>5 (yellow)</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>9 (green)</td>
<td>21</td>
</tr>
<tr>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>13 (blue)</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>17 (violet)</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>6</td>
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<tr>
<td>19</td>
<td>7</td>
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<td>20</td>
<td>8</td>
</tr>
<tr>
<td>21 (red)</td>
<td>9</td>
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<td>22</td>
<td>10</td>
</tr>
<tr>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
</tr>
</tbody>
</table>

are based on the various determinants of color schemes previously described.

Selection of a color scheme for a residence usually begins with the living area. The color combinations used in the remainder of the residence may then be harmonized with the predominant color selected for this area. Two color schemes are listed in Table III for the living room, the main room in a living area. The first scheme is
constructed of analogous colors of blue, with the floor
carpet in the darkest value of blue, the walls lighter than
the floor, and the ceiling lighter than the walls. The
drapery material is a blue-violet hue, tinted with white;
the furniture is upholstered with blue-green tinted white
and with a tweed of blue-green and blue-violet.

TABLE III
EXAMPLES OF COLOR SCHEMES FOR LIVING ROOMS

<table>
<thead>
<tr>
<th>Location</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scheme I: Analogous</td>
</tr>
<tr>
<td>ceiling</td>
<td>II-13 tinted 75% white</td>
</tr>
<tr>
<td>walls</td>
<td>II-13 tinted 25% white</td>
</tr>
<tr>
<td>floor</td>
<td>I-13</td>
</tr>
<tr>
<td>drapery</td>
<td>I-13 tinted 50% white</td>
</tr>
<tr>
<td>upholstery</td>
<td>I-13 tinted 25% white; I-11 &amp; 15 tweed</td>
</tr>
</tbody>
</table>

|          | Scheme II: Complementary                  |
| ceiling  | II-white                                   |
| walls    | II-21 tinted 50% white                    |
| floor    | oak wood flooring, oriental area rug      |
| drapery  | I-21                                       |
| upholstery | I-9 (various weaves and textures)         |

The second living room color scheme is constructed of a
complementary arrangement of colors, selecting the red of
the oriental rug for the predominant color (walls and dra-
pery). The contrasting color of green is chosen for the
upholstery.

Included in a living area is the dining room. The
color scheme selected for this room constitutes a triagonal
arrangement of colors, with green as the predominant color and with orange and violet as subordinate colors. As in the first living room color scheme, the floor is the darkest color, with the walls lighter than the floor and the ceiling lighter than the walls. The window treatment includes a green tie-back over-drapery with an orange glass curtain. The upholstery picks up the other color which forms the triangle, violet. Table linens are selected colors of orange, because orange complements foods.

TABLE IV
EXAMPLE OF A COLOR SCHEME FOR THE DINING ROOM

<table>
<thead>
<tr>
<th>Location</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>ceiling</td>
<td>Scheme: Triagonal</td>
</tr>
<tr>
<td></td>
<td>II-9 tinted 50% white</td>
</tr>
<tr>
<td>walls</td>
<td>II-9 tinted 25% white</td>
</tr>
<tr>
<td>floor</td>
<td>I-9</td>
</tr>
<tr>
<td>drapery</td>
<td>I-9 tie-back over-drapery; I-1 glass curtain</td>
</tr>
<tr>
<td>upholstery</td>
<td>I-17</td>
</tr>
<tr>
<td>linens</td>
<td>I-1</td>
</tr>
</tbody>
</table>

The third area included in a living space is the family room or den. Two color schemes have been chosen for this activity area. The first scheme is a triagonal arrangement with orange as the predominant color and green and violet as subordinate colors.

The second color scheme for the family room is based on a complementary arrangement, with orange as the predominant.
color and blue as its contrasting hue. The walls are paneled with wood and the ceiling painted a light blue to give a cool atmosphere. The floor is tiled with vinyl in a burnt orange color to harmonize with the wood walls. The area rug is a tweed of blue and orange. The draperies are stripes of orange and white, and the upholstered furniture is covered in solids of orange and blue.

**TABLE V**

**EXAMPLE OF COLOR SCHEMES FOR THE FAMILY ROOM**

<table>
<thead>
<tr>
<th>Location</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>ceiling</td>
<td>Scheme I: Triagonal</td>
</tr>
<tr>
<td></td>
<td>white (acoustical tile)</td>
</tr>
<tr>
<td>walls</td>
<td>II-1 with natural wood trim</td>
</tr>
<tr>
<td>floor</td>
<td>natural wood (stained II-1 shaded 75% black)</td>
</tr>
<tr>
<td>drapery</td>
<td>I-1 tinted 25% white</td>
</tr>
<tr>
<td>upholstery</td>
<td>I-9 &amp; 17 stripes; solid hues of I-9 and I-17</td>
</tr>
</tbody>
</table>

| ceiling  | Scheme II: Complementary                                              |
| walls    | II-13 tinted 50% white                                                |
| floor    | natural wood paneling                                                 |
| drapery  | I-1 shaded 25% black vinyl; I-1 & 13 tweed area rug                   |
| upholstery | I-1 & white stripes                                               |
|          | I-1 and I-13                                                          |

The second area to be considered in a residence is the sleeping area. Two examples of bedroom color schemes are given, the first suggesting a feminine color selection, with analogous colors predominantly in yellow. The second color scheme is suited to a masculine taste using complementary
### Table VI

**Examples of Color Schemes for Two Bedrooms**

<table>
<thead>
<tr>
<th>Location</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ceiling</strong></td>
<td>Scheme I: Analogous</td>
</tr>
<tr>
<td></td>
<td>II-4 shaded 25% black</td>
</tr>
<tr>
<td><strong>walls</strong></td>
<td>II-4 shaded 50% black</td>
</tr>
<tr>
<td><strong>floor</strong></td>
<td>I-7 shaded 50% black</td>
</tr>
<tr>
<td><strong>drapery</strong></td>
<td>I-5 and white stripes</td>
</tr>
<tr>
<td><strong>upholstery</strong></td>
<td>I-3 &amp; 7 tweed; pure hues of I-3 and I-7</td>
</tr>
<tr>
<td><strong>bedspread</strong></td>
<td>I-5 &amp; white stripes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ceiling</strong></td>
<td>Scheme II: Complementary</td>
</tr>
<tr>
<td></td>
<td>II-1 tinted 50% white</td>
</tr>
<tr>
<td><strong>walls</strong></td>
<td>paneled wood (stained II-1 shaded 50% black)</td>
</tr>
<tr>
<td><strong>floor</strong></td>
<td>natural wood; area rug of I-1 &amp; 1 shaded 50% black</td>
</tr>
<tr>
<td><strong>drapery</strong></td>
<td>I-1 &amp; 13 stripes</td>
</tr>
<tr>
<td><strong>upholstery</strong></td>
<td>I-1 shaded 50% black; I-13</td>
</tr>
<tr>
<td><strong>bedspread</strong></td>
<td>I-1 shaded 50% black</td>
</tr>
</tbody>
</table>

Colors, predominantly orange, with blue as the subordinate color.

The feminine-type color combination is in shades of yellow accented with white in the draperies and bedspread. The masculine-type color scheme has wood paneled walls and warm colors of orange to blend with the wood tones.

A bathroom color scheme usually has brighter colors than a bedroom color scheme. This type of scheme may be a triangular arrangement with red as the predominant color and yellow and blue as the subordinate colors.
TABLE VII
EXAMPLE OF A COLOR SCHEME FOR THE BATHROOM

<table>
<thead>
<tr>
<th>Location</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>ceiling</td>
<td>Scheme: Triangular white</td>
</tr>
<tr>
<td>walls</td>
<td>II-21 tinted 50% white</td>
</tr>
<tr>
<td>wall tile</td>
<td>II-21 tinted 50% white</td>
</tr>
<tr>
<td>floor tile</td>
<td>II-21 tinted 25% white</td>
</tr>
<tr>
<td>drapery</td>
<td>I-5 &amp; I-13 &amp; I-21 stripes or plaids</td>
</tr>
<tr>
<td>counter top</td>
<td>II-13 tinted 50% white</td>
</tr>
<tr>
<td>linens</td>
<td>I-5; I-13; I-21</td>
</tr>
</tbody>
</table>

The ceiling of the bath is painted white to increase the size of this usually small room. The walls and wall tile are light red; the floor tile is a deeper red than the walls; the counter top is a tint of blue; the fixtures are white; and linens are chosen in sets of red, yellow, and blue.

The kitchen is the main room for the service area. The selected color scheme for this example is a complementary combination, with yellow as the predominant color and violet as its contrasting color.

This color combination for the kitchen gives a warm, cheery feeling in the yellow plus the cool feeling of violet. The yellow will be pleasing for early morning breakfast, and the violet will add to the pleasantness of preparing the evening meal. The yellow of the vinyl floor
TABLE VIII
EXAMPLE OF A COLOR SCHEME FOR THE KITCHEN

<table>
<thead>
<tr>
<th>Location</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>ceiling</td>
<td>Scheme: Complementary</td>
</tr>
<tr>
<td></td>
<td>II-5 tinted 50% white</td>
</tr>
<tr>
<td>walls</td>
<td>II-5 tinted 25% white</td>
</tr>
<tr>
<td>floor</td>
<td>II-3 shaded 25% black</td>
</tr>
<tr>
<td>drapery</td>
<td>I-5 &amp; 5 shaded 25% black stripes</td>
</tr>
<tr>
<td>countertop</td>
<td>II-17 tinted 25% white</td>
</tr>
<tr>
<td>linens</td>
<td>I-17</td>
</tr>
<tr>
<td></td>
<td>(stainless steel appliances)</td>
</tr>
</tbody>
</table>

is shaded with black so as to require less maintenance than a lighter color.
CHAPTER BIBLIOGRAPHY


A knowledge of the additive and subtractive principles of color-mixing is very important to the interior designer as he must work with both types of mixing in preparing an interior color scheme. With upholstery, carpets, draperies, and other textile-covered accessories, the interior designer uses the additive principle of color-mixing. With paint pigments for walls and ceilings, and some types of floor-coverings, the subtractive principle of color-mixing is used by the designer.

For an interior designer to be able to use both the additive and subtractive color-mixing principles effectively in an interior, he must have a reasonable knowledge of the basic theories concerning color as presented in Chapter II. In addition to this knowledge, the designer must be aware of the psychological effects that colors have upon people, and of the personalities of the people who will occupy the interior area. Thus informed of all variables with which he must work, the designer can competently select an appropriate color scheme.

To produce a designer's modus operandi for use in developing interior color schemes, color-reference samples are prepared representing both additive and subtractive
systems of color-mixing. A collection of twenty-four textile samples is woven, using the three additive primary colors in yarns of orange, green and violet. The colors of these samples may be seen as additive mixtures. For purposes of correlation, a similar collection of twenty-four paint pigment samples is prepared according to the subtractive principle of color-mixing. The three subtractive primary colors of yellow, magenta, and cyan are used for these samples. These two collections of color-reference samples are found in the third chapter.

The determinants of color usage in interiors are stated in the fourth chapter. These include psychological color associations, functional and visual aspects of color quality, and architectural requirements. From this investigation three types of interior color applications are developed: the complementary color scheme based on the contrast of two colors, the triagonal color scheme based on three colors equally spaced around the Ostwald hue circle, the analogous color scheme composed of colors within one hue family.

To aid the interior designer in constructing harmonious color combinations, Table II matches predominant colors, either additive or subtractive, to related subordinate colors, also either additive or subtractive. The related subordinate colors are divided into three categories of complementary, triagonal, and analogous colors, corresponding to the three applications of color schemes. To
illustrate how this table may be used by the designer, applied color schemes are developed for several areas of a residence, based on the various determinants of colors.

Conclusions

This research develops a technique of interior color application based on the relationship between additively-mixed colors and subtractively-mixed colors. It is recognized that constructions of color schemes for interiors may be based on several methods of color application, but it is concluded that this one technique offers a wide range of color combinations for use by the interior designer. Choosing interior colors need not be an intuitive task approached with apprehension. By methodically acknowledging and coming to terms with each determinant involved with the interior, the designer may select colors with competence.

The color-reference samples developed for this technique of color application are intended to define the two principles of color-mixing and aid in the construction of color schemes. It is recognized that textiles are not available for use in interiors which are replicas in color and design of the additive color-reference samples prepared for this study. For this reason the samples are intended to serve, not as solutions to color schemes, but as reference colors, useful in making visual comparisons between additive color and subtractive color mixtures.
The applied color scheme examples are provided to illustrate how the two color-mixing principles may be related through the use of predominant and subordinant colors. The color applications presented, complementary, triagonal, and analogous, are three of the important ways which color schemes may be constructed, yet the principles of relationship of additively and subtractively mixed colors developed for these schemes may be applied to others not discussed.

Concerning the applied color schemes, it may be possible that in a room setting, some colors as listed in this guide would be too powerful or too weak, or they may not all be conducive to the use of the interior. Unfortunately, it was beyond the scope of this research to construct an actual interior setting to apply each color scheme and test it for its overall effectiveness, but it is hoped that the groups of color combinations will be useful in illustrating the designer's mode of operation.

Recommendations

It must be stressed here that the visual effects of additive mixing evident in the textile color-reference samples prepared for this research are applicable to woven textiles and not to printed fabrics. These fabrics are printed with subtractively-mixed dyes. While it is possible that the visual effects of some small printed repeat designs would be caused by an additive mixing, as in the case of woven textiles of varied colored yarns, large-patterned
prints would be seen differently, because the colored areas would remain visually distinct. A companion study of how printed fabrics visually relate to other interior colors could possibly be the basis of another research for the interior design profession.

Further research into how people react to interior surroundings of differing color combinations as they may be experienced in the home could yield many interesting facts in the study of human involvement in the environment. This type of research has been conducted to a limited extent in clinical experiments, but not to any large degree with a "normal" family unit, and it is with this, the "normal" family unit, that the interior designer must work.
After-image.--In viewing a color, the human eye has a tendency to bring up a strong response to that color's opposite hue. As an example, when staring at a red area and then at a neutral surface, a sensation of green will be experienced. The after-image of yellow will be blue. The phenomenon has great influence over color effects and gives intensity to strong contrasts and mellowness to blended color arrangements. Recent scientific experiments indicate that after-image effects take place in the brain rather than in the eye (3, p. 92).

Analogous Colors.--These colors are within the same hue family, that is, all blues, greens, reds, et cetera. Analogous hues may be blended without danger of clash. Colors in analogous groupings assume more personality (4, p. 35).

Brightness.--This is the quantitative aspect of the mental image of the color. The image appearance of the color is measured in terms of its apparent amount of brightness. Brightness increases with the physical intensity of the light which produces the color (8, p. 118, p. 121).
Chroma.—Chroma is the degree of departure of a color sensation from that of white or gray. It is the intensity of distinctive hue, or color intensity (10, p. 99).

Color.—Color is a visual sensation or mental and emotional interpretation of what the eye records. It gives quality to an object or scene. In terms of physics, it is the transition of radiant energy to the mental quality of color, or a psychophysical stimulus (3, p. 27; 7, p. 205).

Color Harmony.—Color harmony refers to a grouping of colors which will appear pleasant to the observer when viewed in an ensemble. Color harmony may be similar or contrasting in make-up. Similar harmony is restful but sometimes monotonous. This type of harmony is produced from colors that are located near each other on the hue circle, including analogous colors. Contrasting harmony is interesting, but sometimes disturbing if the colors are too striking. This type of harmony is produced by combining colors that are located far apart on the hue circle, including complementary and triagonal colors (1, p. 129; 6, pp. 121-122).

Color Sensation.—This is a luminous visual sensation possessing hue and saturation (11, p. 158).

Color Stimulus.—This may be any luminous stimulus producing color sensation (11, p. 158).
Complementary Colors.—Any two colors which, when mixed in the proper amounts, subtract all of the visible light rays are termed complementary colors. These are located opposite each other on the hue circle (1, p. 105; 7, p. 216).

Hue.—Specifically and technically, hue is a distinctive quality of coloring in an object or on a surface, such as red, yellow, blue, green, et cetera (10, p. 101). Refer to Selective Absorption.

Intensity.—This describes the degree of purity or strength of a color, the clarity or dullness. It refers to the amount of the predominant hue that is seen. Pure red is completely saturated with red, dull or weak red gives the sensation of only a little redness (3, p. 148).

Light.—Light is adjectively applied to colors of high luminosity and more or less deficient in chroma (10, p. 101).

Luminosity.—In physics this refers to the intensity of light in a color. It may be measured photometrically (10, p. 101).

Maxwell Color Disks.—These disks, each a specific color, are attached to a motor-driven shaft and spun at high speed. The eye of the viewer is unable to distinguish the separate colors and sees only their additive mixture. This sensation is comparable to observing a composite pattern at a distance. The separately colored disks are slit radially.
so that one disk may be inserted with another disk, displaying variable amounts of colors (2, pp. 60-61; 4, p. 16; 9, p. 61).

**Pigment.**—This is any substance that is or can be used by painters to impart color to a surface (10, p. 102).

**Primary Colors.**—These are colors which may be used to form a mixture of other colors (7, p. 111).

**Primary Colors, Chemistry.**—The chemistry of color involves pigments and compounds. It has three primary tones: magenta, yellow, and cyan, which when mixed together give various other hues. Magenta and yellow give orange, yellow and cyan make green, and cyan and magenta form violet. These mixtures are subtractive, working down toward black, the result of combining the three primaries (3, p. 84).

**Primary Colors, Physics.**—The physics of color involves light. The three primaries are orange, green, and violet. Orange and green light blend to give yellow, green and violet make a clear, light cyan; and violet and orange produce magenta. Light mixtures are additive, with white the unity of all hues (3, p. 84).

**Primary Colors, Visual.**—The sensory aspect of color is visual and embraces physiology and psychology. The human eye discerns four primary hues: red, yellow, green, and blue. All are unique and bear no resemblance to each other,
yet all other hues seem to be blends of these four primaries. Visual mixtures tend to work toward neutral gray (3, p. 84).

Purity.—This is the ratio of the monochromatic component to the total intensity (7, p. 106).

Saturation.—Saturation is the freedom from white sensation which is attributed to any color sensation, whereas a full color may be distinguished from a mixture with gray having the same brightness. The saturation diminishes as the amount of white is increased. It may be measured in the percentage of hue in a color: pale or deep, weak or strong (7, p. 118; 10, p. 103; 11, p. 160).

Selective Absorption.—Almost all materials absorb some of the light which falls on them and have some selective action since they absorb more at some wave lengths than at others (7, p. 58).

Shade.—This is a mixture of a color with black whereby the brightness of the resulting sensation is decreased (11, p. 160).

Spectrum.—In physics the spectrum is the continuous band of light showing the successive prismatic colors, or the isolated lines or bands of color, observed when rays from such a source as the sun is viewed after having been passed through a prism (prismatic spectrum) or reflected.
from a diffraction grating (diffraction or interference spectrum) (10, p. 104).

**Subtractive Mixture.**—This type of color mixing causes the selective absorption of light by colorants with the remainder of light being reflected (7, p. 267).

**Tint.**—An addition of white color results in a tint whereby the brightness of the resulting sensation is increased and the saturation is decreased (11, p. 160).

**Value.**—The lightness or darkness of a color is referred to as the value and gradates from white to black (6, p. 115).
APPENDIX BIBLIOGRAPHY


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Books


**Articles**


**Reports**