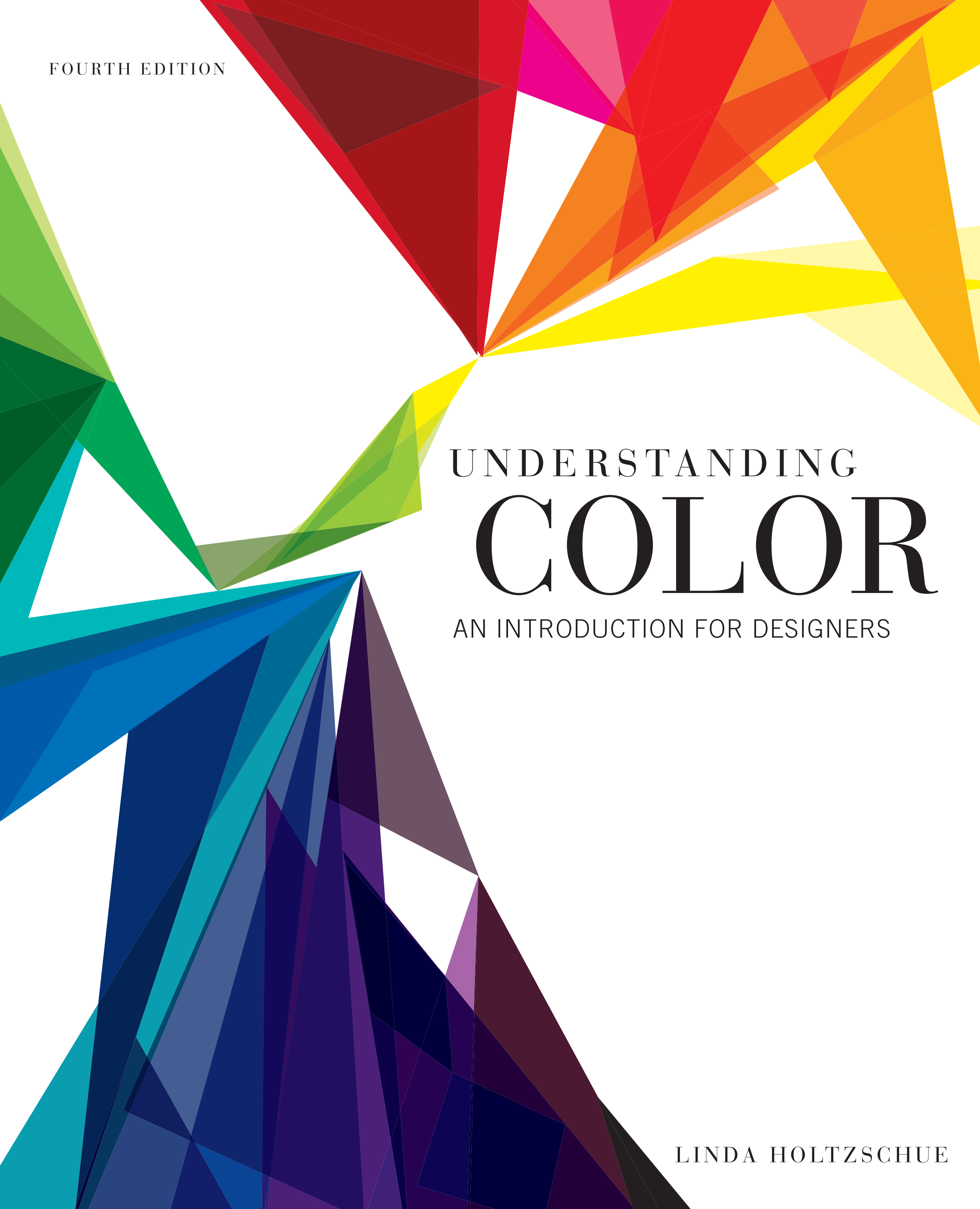
FOURTH EDITION

UNDERSTANDING COLOR

AN INTRODUCTION FOR DESIGNERS



LINDA HOLTZSCHUE

UNDERSTANDING COLOR

An Introduction for Designers
Fourth Edition

Linda Holtzschue

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DEDICATION

To my children Alison, Adam, and Sara, and the wonderful partners they have brought into our lives; to my grandchildren Amanda Carrico Schloss, Katherine Rose Schloss, and Daniel Elias Holtzschue; and most of all to my husband Karl, whose patience and support made this book possible.

ACKNOWLEDGMENTS

This fourth edition of *Understanding Color* would not have been possible without the generosity of friends and colleagues, both old and new. I was delighted that Jennifer Perman, who designed the second and third editions and created many of the illustrations, was available to design this edition as well, and that my editor Margaret Cummins, who cheered me on through the two last editions, continued in that role for this one. I could not have done this book without the contributions, guidance, and support of Steven King, Bob Stein, Laurent de Brunhoff, Phyllis Rose, Carin Goldberg, Ron Lubman, Emily Garner, Kenneth Charbonneau, Wilsonart, Mark Stevenson, Stephen Gerould, Dan Brammer, Jamie Drake, Adobe Systems, Farrow and Ball, David Setlow and Stark Carpets, Edward Fields Carpets, Tai Ping Carpets, Safavieh Carpets, The Color Association of the United States, Color Marketing Group, Elizabeth Eakins, Sanderson, First Editions, Erika Woelfel of Colwell Industries, X-Rite Corporation, Alison Holtzschue, Gwen Harris, my friends at Benjamin Moore, and anyone I may inadvertently have missed. Thank you, all.

PREFACE

More changes have taken place in the way that designers work with color in the last few decades than have occurred over the last few centuries. Technology has created a tectonic shift in the everyday experience of color. Colored light, once a limited area of interest to designers, is now the primary medium of the studio workplace. Color is a whole new world, and at times a very confusing one.

This is a book for everyone who uses color. It is written for design students and sign painters, architects and carpet salespeople, graphic designers and magicians. It is a road map to the relationships between colors, and even more, to the relationships between real colors and virtual colors. It is guide to using color freely, comfortably, and creatively without dependence on complicated theories or systems. This is a book about learning to see—in the new way as well as the old.

This book includes a workbook component that is available online at www.wiley.com/go/understandingcolor4e.

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1

AN INTRODUCTION TO COLOR STUDY

The Experience of Color / Color Awareness / The Uses of Color / Color-Order Systems / Color Study

Color is essential for life.

—*Frank H. Mahnke*

Color is stimulating, calming, expressive, disturbing, impressional, cultural, exuberant, symbolic. It pervades every aspect of our lives, embellishes the ordinary, and gives beauty and drama to everyday objects. If black-and-white images bring us the news of the day, color writes the poetry.

The romance of color exists for everyone, but color has an additional aspect for design professionals. Forms, colors, and their arrangement are the foundation elements of design, and of these elements, color is arguably the most powerful weapon in the designer's arsenal. A skilled colorist understands what color is, how it is seen, why it changes, its suggestive power, and how to apply that knowledge to enhance the marketability of a product. Whether the product is a graphic design, an item of apparel, an interior, automobile, toaster, garden, or anything else, good coloring can determine its success or failure in the consumer marketplace.

The Experience of Color

Color is, first, a sensory event. Colors are true sensations, not abstractions or ideas. The beginning of every color experience is a physiological response to a stimulus of light. Colors are experienced in two very different ways. The colors on a monitor screen are seen as direct light. The colors of the physical world—of printed pages, objects, and the environment—are seen as reflected light.

The perception of colored light is a straightforward experience: light reaches the eye directly from a light source. The experience of real-world color is a more complex event. Real-world colors are seen indirectly, as light reflected from a surface. For tangible objects and printed pages, light is the *cause* of color, colorants (like paints or dyes) are the *means* used to generate color, and the colors that are seen are the *effect*.

All colors, whether they are seen as direct or reflected light, are unstable. Every change in light or medium has the potential to change the way a color is perceived. The color of a carpet underfoot is very different from that of its image on a screen, and each of these is different from its illustration on a printed page. In addition, the same color will appear to be different colors depending on its placement relative to other colors.

Not only are colors themselves unstable, ideas about colors are unstable as well. The color that one person identifies as "true red" will be a bit different from another's idea of "true red." When colors are used as symbols, their meanings are equally mutable. A color used symbolically in one context may have another meaning entirely—and even be called by another name—when it appears in a different situation.

Most of the work of the design industries today is done in images of direct light, on a monitor, for products that will ultimately be produced as goods or printed pages. Are the screen image and the product the same color? Can they be the same color? Which one is the "true" color—the one on the screen, or the one that is the actual object? Is there such a thing as a "true" color at all?

Designers *use* color. Their concern is with effects, not with words, ideas, or causes. Understanding what is seen, and how and why it is seen—how colors work—is background knowledge that supports the *art* of color. Designers work with color every day in a comfort zone; a healthy mix of fact, common sense, and intuition. A skilled colorist exploits the instabilities of color and uses them to create interest and vitality in design.

We understand color in much the same way that we understand the shape of the earth. The earth is round, but we experience it as flat, and act on it according to that practical perception of flatness. Color is light alone, but it is experienced so directly and powerfully that we think of it as a physical entity. No matter what we may understand about the science of color, or what color technology is available, we believe our eyes. Color problems in the design industries are solved with the human eye. *Designers work with color from the evidence of their eyes.*

Color Awareness

Color is sensed by the eye, but the perception of color takes place in the mind, and not necessarily at a conscious level. Colors are understood in context. They are experienced at different levels of awareness depending on how and where they are seen. Colors may be perceived as an aspect of form, as light, or as surroundings. Colors permeate the environment, are an attribute of objects, and communicate without words.

Environmental color is all-encompassing. Both the natural world and man-made environments immerse us in colors, whether they are the cold whites of Antarctica, the lush greens of tropical forests, the accidental color compositions of urban streets, or the controlled-color environments of architecture, landscape design, interior design, or theater design.

Surrounding colors have a powerful impact on the human body and mind, but most of the time they are experienced with an astonishing lack of awareness. Environmental color is noticed only when it is a focus of attention, like a dazzling sunset or a freshly painted room. Someone who expresses a dislike for the color green may nevertheless take enormous pleasure in a garden, describing it as a blue or yellow garden, when in fact the surroundings are overwhelmingly green, with blue or yellow present as only a small part of the whole.

The colors of objects are perceived very directly. The separateness of an object allows the viewer to focus both eye and mind on a single entity and a single color idea. We are the most consciously aware of color when it is an attribute of a defined object: a blue dress, a red car, a yellow diamond.

Figure 1-1.
Environmental Color. Color surrounds us at all times, whether the setting is man-made or natural. *Photograph courtesy of Phyllis Rose Photography, New York & Key West.*

Figure 1-2.
Environmental color. The colors of the natural environment are complex and beautiful. *Photograph courtesy of Phyllis Rose Photography, New York & Key West.*

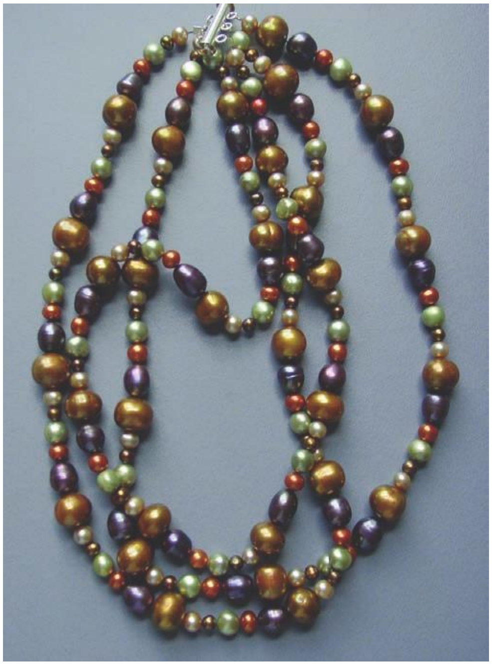


Figure 1-3. *Object Color.* Unexpected color in natural pearls adds surprise and individuality to a classic jewelry form. *Jewelry design by Suzy Arrington.*

Graphic colors are the colors of images: painted, drawn, printed, or on-screen. *Graphein*, the Greek root of the English word "graphic," means both "writing" and "drawing." Whether a graphic design is made of written words, illustrations, or both, its purpose is to communicate. It tells a story, sends a sales pitch or political message, even conveys emotion. Color in a graphic design is an integral part of the message. Graphic colors are experienced on many levels; conscious and unconscious, sensory and intellectual, at the same time.

Figure 1-4. *Graphic Color.* Color adds meaning to the written word.

The Uses of Color

Color is recognized universally as a natural component of beauty. The Russian language word for *red* has the same root in Old Russian as the word for *beautiful*. But colors are far more than just beautiful; they are *useful.* Color can be used to communicate ideas and emotions, to manipulate perception, to create focus, to motivate and influence actions.

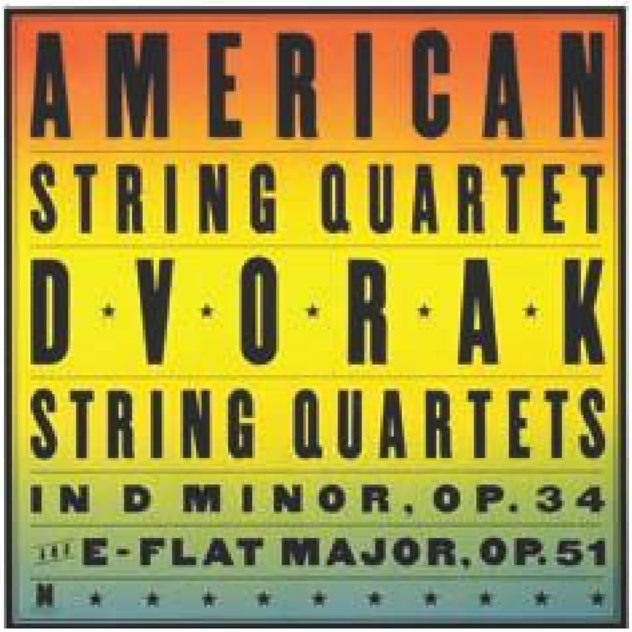


FIGURE 1-5.
Color Conveys Mood. An off-beat combination of colors perfectly expresses the edgy modernity of Dvorak's Piano Concerto in G Minor. *Image courtesy of Carin Goldberg Design.*

Color can be used as pure function, to increase or reduce available light. Light colors reflect light and increase the available light in a space; dark colors absorb light and reduce it. A room painted pale ivory will reflect more light—actually be lighter—than the same room painted dark red. When a room is dark, adding additional illumination alone will not necessarily solve the problem. If the walls are absorbing light, they will continue to do so. Illumination and color are equals in environmental space: it is the balance of the two that establishes the level of brightness.

Color can modify the perception of space, creating illusions of size, nearness, separation, or distance. Colors can be chosen to minimize or obscure objects and spaces, or to delineate space, separating one area from another. Color can be used to create continuity between separated elements in design, or to establish emphasis or create focus in a composition.

Color can be a visual expression of mood or emotion. Intense colors and strong contrasts communicate action and drama. Gentle colors and soft contrasts convey serenity. Color can be also used to generate emotional response. Colors have physiological effects on the body. They can be chosen to stimulate, or to calm. They can be used to arouse a nonvisual sense, instill unconscious motivation, alter behavior or induce mood.

Colors can be a nonverbal language; communicating ideas without a single word. They can be used to represent a nation or institution, a product, or an idea. National flags are identified by color. IBM is Big Blue. Harvard is crimson. Colors can both symbolize and communicate social position. In ancient China the emperor alone wore yellow. Roman Catholic priests wear black; Tibetan priests, saffron yellow.

Figure 1-6. *Orange Alert.* Traffic cones warn drivers to take extra care.

Colors can be used to alert, or warn. A flashing red light evokes a different response than a green one. Violet warns of radiation danger.

Figure 1-7. *Color Identifies.* An enormous filing system is made more manageable by tabs of different colors.

Color identifies. It provides instant discrimination between objects of similar or identical form and size. The red file holds unpaid bills; the green file the paid ones. Color is associative. The ordinary things of everyday life are characterized by color associations. They can all be found in the Yellow Pages.

Color-Order Systems

One way to understand color is to organize it into a system; to hypothesize and illustrate a structured model of color *relationships*. The color-order model, or color system, is a thread that runs from the earliest writings on color, to the absolute present, to tomorrow. These countless different and competing systems organize color in various ways, each convinced of its own rightness. But color is such an enormous topic that no single color-order system can be truly inclusive. In the early 1930s, The National Bureau of Standards tried to categorize and describe 10 million colors for scientific and industrial use. The result was a massive color-name volume and a breathtaking failure. The group "grayish-yellowish-pink," for example, included about thirty-five thousand samples.[1]

Today that effort might call for categorizing the more than 17 million colors available in design software, and even that number is not as great as the number of colors that can be distinguished by the human eye. More successful systems address a narrower range of issues. These systems fall into three groups:

Technical-scientific color-order systems
Commercial color-order systems
Intellectual-philosophical color-order systems

Technical-scientific systems are the province of science and industry. They measure color under specific and limited conditions. Most deal with the colors of light, not the colors of objects. One means of measuring the color of light is by determining the exact temperature in degrees Kelvin (K) of a piece of metal, called a blackbody, as it heats up. The color of a blackbody changes at specific temperatures, so that "color temperature" in the scientific sense refers to the point in degrees K at which the blackbody changes color as it heats, from yellow, to red, to blue, to white.

The International Commission on Illumination, known as the CIE, or Commission Internationale de l'Eclairage, has developed a color triangle that locates the color (in degrees K) of any light source. The CIE color triangle is mathematical and based on the human range of vision. It is said to be the most accurate of the color description models but is highly theoretical—so theoretical, in fact, that according to a CIE spokesman, it cannot be accurately illustrated. It is also not applicable to many technologies, including color printing and color monitors, so these must use other color models.

Another system, the Color Rendering Index (CRI), evaluates the way in which a given light source renders the colors of objects in comparison to a chart of eight standardized colors. Colors are judged in relation to daylight, and incandescent light is rated as best for illuminating the natural world because of its similarity to daylight.

Technical systems of color organization are not a part of the day-to-day work of the design studio. The artist or designer, for example, has a concept of "color temperature" that is something entirely different. Technical systems are, however, of value in maintaining quality control at the manufacturing level.

Commercial color-order systems are systematic arrangements of colors meant to assist the user in making selections from the colors available in a particular product line. There are two broad categories of commercial color systems: true *color systems* and *color collections*.

True color systems are based on a theory of colors and are published as a full range of colors arranged in a visually logical format. They attempt to illustrate all possible colors that can be produced within a specific medium, like paints or printing inks, and offer the option of adding colors beyond those illustrated. The Benjamin Moore® Color System, for example, includes over 3300 paint colors and offers a computer-matching option to create custom colors that do not appear in the printed collections.

One of the most widely known commercial color order systems is the PANTONE MATCHING SYSTEM®,[2] which provides a palette of standardized colors for a wide range of products ranging from printing inks to software, color films, plastics, markers, and color-related tools and products for use by designers and manufacturers. The most familiar are the swatch books of colors that can be printed using four-color (cyan, magenta, yellow, and black; or CMYK) process printing inks. The colors are arranged in a visually logical way, and each indicates the percentage of each of the four CMYK colors that mix to produce it. Bright red PANTONE® P57-8C, for example, is noted as C0, M100, Y66, K0. A dull red, PANTONE P50-8C, is made up of C0, M99, Y91, K47. Colors that do not appear on the charts can be produced by tweaking the percentages. Pantone offers similar charts for six-color printing inks, solid color inks, and a host of related color products.

Figure 1-8. *Commercial Color Order Systems.* Pantone offers swatch books of colors that can be printed using four-color process printing inks as well as swatch books for six-color, solid color, and specialty inks.

Color collections are narrower in scope. They offer a limited number of colors, often with a theme or point of view, to help the user in making a selection within a single product or group of related products. Color collections do not attempt to include all possible colors. Instead, they offer a color range intended to meet most needs within a specific target market or industry. A collection of historical paint colors, or Web or mail-order catalog color options, are color collections. The number of samples can vary widely. Coats and Clark, for example, offers more than 900 colors of sewing thread in its Global Colour Reference of Industrial Apparel Thread Shades. Old Village, a specialty paint company, offers only 25 paint colors, each painstakingly created to simulate an historic original, along with a very few colors in specialty products like buttermilk paint. There are countless numbers of these limited color collections available for use by artists, designers, and the general public.

Figure 1-9. *Color Collections.* A representative sampling of Farrow and Ball paint colors; part of a larger collection of colors based on historical prototypes. *© Farrow and Ball 2005. All rights reserved. No part of a colour card may be reproduced without prior permission of Farrow and Ball.*

Commercial color systems and collections are practical both in intent and in fact. They do not contribute to an understanding of color, but they were never intended to do so. Within their limitations they are invaluable as aids in specifying colors for design as well as other purposes.

Intellectual-philosophical systems explore the meaning and organization of color. Artists (famous and not-so-famous) have always written on color, but a fascination with the topic has never been limited to the world of art. Plato and Aristotle, Newton, Goethe, and Schopenhauer wrote about color, as did many other scientists and philosophers.

The late seventeenth and early eighteenth centuries saw a flowering of writing on color whose influence persists to the present day. Two threads of inquiry run through these studies: first, the search for a perfect color-order system; second, the search for laws of harmony in color combinations. The two paths have converged into the present-day field of study known as *color theory*.

Early writers made no distinction between the art of color and the science of color. The colors of light and the colors of objects were dealt with as a single discipline. The natural sciences developed quickly into separate fields of study: biology, mathematics, physics, chemistry, and later, psychology, among others, but even color theorists whose focus was the arts continued to approach color as an scientific discipline. The aesthetic and philosophical color-order systems they proposed were viewed as scientific information until well into the twentieth century. Today, writers on color still come from scientific, artistic, and philosophic disciplines, but color theory for artists and designers has been separated from science. Color theory has, at last, its own place in the arts.

Color Study

It makes no difference whether color is seen as light on a monitor screen or as an attribute of a physical object. No matter how color is seen, or in what medium it is rendered, or what other senses seem to respond to it, the experience of color is visual. Color study focuses first on *eye-training*: learning to distinguish in every color sample three objective attributes:

Hue, the name of the color.
Value, the relative darkness or lightness of a color.
Saturation or *chroma*, the relative brilliance or muted quality of a color.

These qualities are independent ideas only for purposes of study. Every color possesses these three attributes. No color can be described fully as only one idea. The emphasis of one quality over the others—of hue-intensity, or lightness, or darkness—gives each single color its individual character. Other qualities of colors, like surface texture, or opacity, or translucency, are additional to these basics.

The second focus of color study is color *control*. The instability of colors cannot be eliminated, but it can be minimized. Designers deal with the instability of color in three principal ways: first, by anticipating the changes that occur when colors are seen under different lighting conditions; second, by adjusting for changes that take place when colors are given different placements relative to one another; and third, by adjusting for changes that take place when colors must be transposed from one medium to another—for example, in illustrating a piece of dyed fabric on a monitor screen.

Finally, color study provides guidelines that enable designers to create consistently effective color combinations. The ability to use color effectively is a skill that can be taught and strengthened. Color *competence* is the ability to problem-solve with color. It is the ability to predict and control, to the extent possible, color effects, and the ability to select and specify colors and combinations that enhance every product or page.

Many color courses taught today have their foundation in the teachings of Albert Munsell (1858–1918) and Josef Albers (1888–1976). Munsell's method follows a classic color-order tradition. It is a formal system based on orderly progressions of the three color qualities hue, value, and saturation. Albers took a more free-spirited approach. He believed that true understanding comes from an intuitive approach to color. He rejected the rigidity of color-order systems and stressed the power of eye-training exercises.

The Albers intuitive approach dominates American color education today. Detached from its background in color-order systems, it is not as accessible an approach to teaching color as it can be. The intuitive approach makes infinitely more sense when it follows an understanding of what color-order systems are about. By learning first to discriminate hue, value and saturation and mastering the concept of intervals, or steps between colors, students acquire skills that make the Albers exercises comprehensible from the start. Color-order systems and the Albers intuitive approach are not alternative ways to study color, nor are they competitive. The first leads seamlessly to the second, and together they embrace an understanding of color without limits or gaps.

Because no two individuals see color in exactly the same way, or share the exact idea of any given color, it is easy to conclude that color study in a class would be (at best) a waste of time or (at worst) a scheduled free-for-all. But there are great benefits from studying color in a group. For every problem assigned there are wrong answers, but there are also many different possible right answers. Twenty students may bring in twenty different, yet equally acceptable, solutions to the same color assignment.

Academic (nondesign) education tends to reward students who find the single "right" answer to a question or assignment. Some students who have been successful in traditional academic areas find this flexible standard of "rightness" very difficult. But the possibility of many right answers for each problem is extraordinarily liberating because it increases exponentially the chances of success. It is also extraordinarily instructive, because seeing a variety of responses, even "wrong" ones, sharpens developing critical skills.

The first step of color study is to enable the student to see colors without the interference of preconceived ideas. Students with a (self-assessed) "good sense of color" may feel inhibited, disoriented, or exasperated at the start. Just as mastering written music may at first slow down a natural musician, learning basic color skills may at first hamper an artist or designer. The inhibiting effect is short-term. There is a moment when learned material becomes reflexive, like the magical moment for children when learning to read ends and reading begins. The ability to work effectively with color is part of a designer's core competence. It is artistic empowerment. The designer who understands color has a competitive edge in every industry.

Endnotes

1 Sloane 1989, page 23.

2 PANTONE® and other Pantone trademarks are the property of and used with the permission of Pantone, LLC.

Chapter 1 Highlights

- Color is a sensory event; a physiological response to a stimulus of light. Color is also unstable. Every change in light or material has the potential to change the way a color is perceived and, in addition, individuals interpret the experience of color in different and personal ways.

- Colors are understood at different levels of awareness. Environmental color, whether natural or man-made, is all-encompassing. The separateness of an object allows the viewer to focus on a single entity and single color idea. Graphic colors are the colors of images: painted, drawn, printed, or on-screen.

- Colors on a monitor screen are seen as direct light. The colors of the physical world are seen as reflected light. Nearly all design today is done on a monitor screen in images of direct light for products that will be seen as reflected light.

- Color can be used as pure function, to increase or reduce available light. It can modify the perception of space, creating illusions of size, nearness, separation, or distance. Color can minimize or obscure objects and spaces and delineate space. It can be used to create continuity between separated elements in design, or to establish emphasis or create focus in a composition. Color can be used to express mood or emotion. Color can be used to alert, or to warn, or to provide discrimination between objects of similar form and size. It can be a nonverbal language; communicating ideas without words.

- A color-order model, or color system, is a structured model of color relationships. Technical-scientific systems measure color under limited conditions, and most deal with the colors of light. Commercial color-order systems are systematic arrangements of colors meant to assist the user in selecting colors from a limited palette. Intellectual-philosophical systems explore the meaning and organization of color.

- True color systems attempt to illustrate all colors and include the option of adding colors beyond those illustrated. Color collections offer a fixed and limited number of colors to help the user in making a selection within a single product or group of related products.

- Color study focuses first on learning to discriminate objective attributes of color: hue, value, and saturation (chroma). The second focus of color study is color control. Color study also provides guidelines for creating effective color combinations.

- Many color courses are based on the writings of Albert Munsell (1858–1918) and Josef Albers (1888–1976). Munsell's system is based on formal progressions of hue, value, and saturation. Albers stressed the power of eye-training exercises.

2 A LITTLE LIGHT ON THE SUBJECT

Light / Additive Color: Mixing Light / Lamps / Lighting Level / Vision / The Illuminant Mode of Vision / The Object Mode of Vision / Subtractive Color: Colorants / Lamps and Color Rendition / Metamerism and Matching / Modifying Light: Surface / Transparent, Opaque, and Translucent / Iridescence / Luminosity / Indirect Light, Indirect Color / Modifying Light: Filters

Colors seen by candelight, Will not look the same by day.

—Elizabeth Barett Browning, "The Lady's 'Yes" 1844

Color is a visual experience, a sensation of light that cannot be verified by other senses: not by touch, taste, smell, or hearing. A colored *object* can be touched, but it is the object itself that is tangible, not its color. Color has no physical substance.

Colors are not only intangible, they also change constantly. Everyone has experienced buying an article of clothing and arriving home to find that it is a different color than it seemed to be in the store, or selecting a paint color and being astonished at the final result. Even the *idea* of a color is unstable. A number of people looking at the same thing often disagree about exactly what color it is.

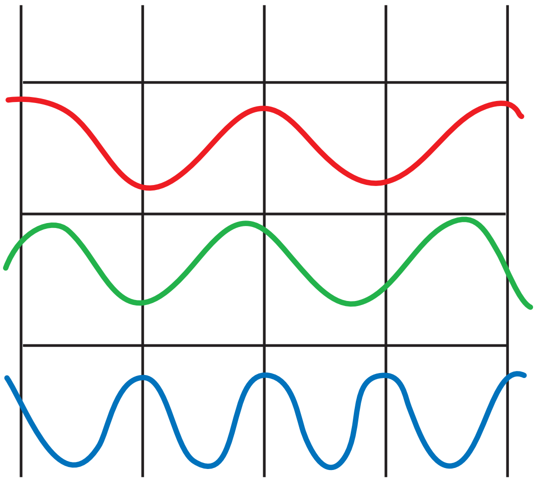
The instability of color has a number of causes. The first of these is the way in which colors are generated by light, reflected from surfaces, and sensed by the human eye. The color of an object is no more permanent or absolute than the light under which it is seen.

Light

Only *light* generates color. Without light, no color exists. Light is *visible energy* that is emitted by a *light source*. A light source can be any one of a number of things: the sun, a luminous panel, a neon sign, a light bulb, or a monitor screen. The eye is a sense organ that is adapted to receive light. The retina of the eye receives a stimulus—the energy signal—and transmits it to the brain, where it is identified as color.

Light sources emit this visible energy in pulses, or waves. All light travels at the same speed, but waves of light energy are emitted at different distances apart, or *frequencies*. The distance between the peaks of these energy emissions is called *wavelength*. Wavelengths of light are measured in nanometers (nm).

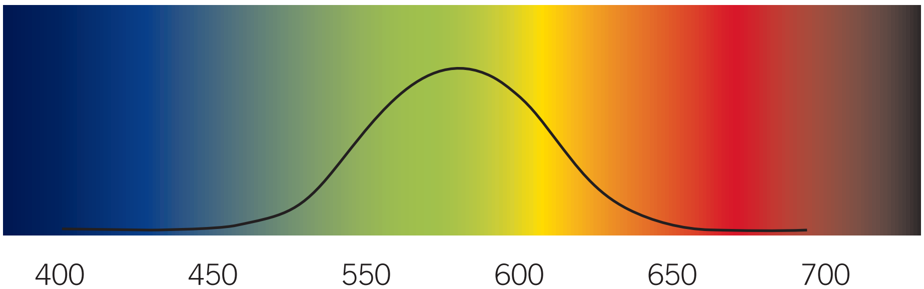
Figure 2-1. *Wavelength*. Individual wavelengths of the visible spectrum are sensed as different colors.



The human eye is able to sense wavelengths of light ranging from about 380 nm to about 720 nm. Individual wavelengths are sensed as discrete (separate) colors, or *hues*. The pure hues of light are defined by measurement. Red is the longest visible wavelength (720 nm), followed in order by orange, yellow, green, blue, indigo, and violet, the shortest visible wavelength (380 nm). ROYGBIV is an acronym for these wavelengths, which are the colors of the *visible spectrum*.

Different light sources emit the various wavelengths (colors) at different levels of energy. One light source may give off a particular wavelength at such a low level of energy that it

Figure 2-2 . *Visible Light*. Human beings are able to sense light (visible energy) between wavelengths of about 380 nm to 720 nm.



is barely visible, while another emits it so strongly that it is seen as brilliant color. Although the color is the same, the intensity of the color experience is very different.

The human eye is most sensitive to light in the middle range of the visible spectrum and sees these colors, the yellow-green range, most easily. Yellow-green light can be sensed at a lower level of energy than other colors. If a light source emits all the wavelengths at roughly the same level of energy, the yellow-green range is sensed as brightest. There is visible light and color beyond the range of human vision. Some animals and insects can sense colors that humans cannot, and both ultraviolet and infrared, colors that lie beyond the ends of the visible spectrum, can be made visible to the human eye with special optical equipment.

Additive Color: Mixing Light

The sun is our fundamental light source. Sunlight is sensed as white, or colorless, but it is actually made up of a mixture of colors (wavelengths) that are emitted in a continuous band. The individual colors of sunlight can be seen when sunlight is passed through a prism. The glass of the prism bends, or *refracts*, each wavelength at a slightly different angle, so that each color emerges as a separate beam. Under the right set of atmospheric conditions water droplets will form natural prisms, and the component colors of sunlight can be seen as a rainbow.

Figure 2-3. *The Component Wavelengths of White Light.* The separate colors (wavelengths) that make up white light can be seen when light is passed through a prism. Each wavelength bends at a slightly different angle and emerges as a separate color. The individual colors of white light can be seen in nature when droplets of water in the atmosphere create a naturally occurring prism. *Photograph courtesy of Phyllis Rose Photography, New York & Key West.*

Other sources, like ordinary light bulbs, also produce white light. A light source does not have to emit all of the visible wavelengths in order for white light to result. White light is produced as long as a source emits the red, green, and blue wavelengths in roughly equal proportions. *Red, green, and blue are the primary colors of light.* A source can emit additional wavelengths (colors) and the light it produces will remain white, but if any one of the three primaries is missing, the light is sensed as a color.

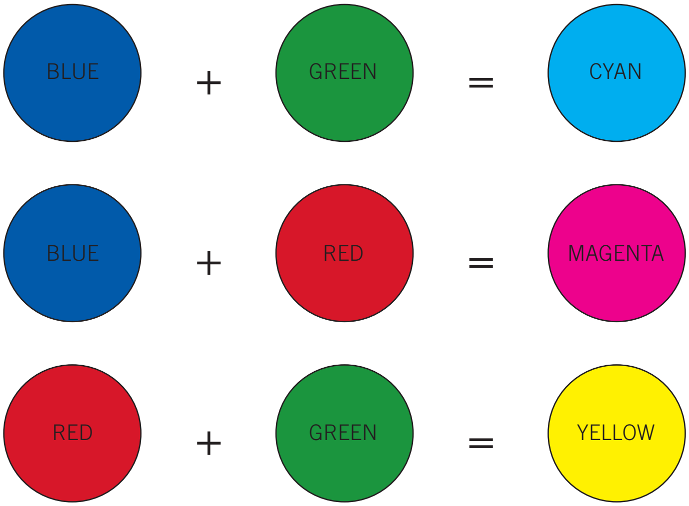


Figure 2-4. *Mixing Light.* The light primaries, red, green, and blue are mixed to form the secondaries cyan (blue-green), magenta (blue-red), and yellow.

Mixing two of the primary colors of light produces a new color. Blue and green wavelengths combined produce cyan (blue-green). Red and blue wavelengths combined produce magenta (a blue-red, or red-violet), and green and red wavelengths combined produce yellow. *Cyan, magenta, and yellow are the secondary colors of light.*

Wavelengths can be combined in unequal proportions to create additional colors. Two parts green light and one part red at equal levels of energy provide a yellow-green; two parts red and one part green produce orange. All hues, including violets and browns that are not found as wavelengths in the visible spectrum, can be produced in light by mixing the light primaries in different proportions.[1]

White or colored light seen as a result of a combination of wavelengths is called an *additive mixture* or *additive color.* "Additive" is a good description of the reality, because new colors of light are created as wavelengths are added to each other.

Lamps

Lamps are the principal man-made light sources. "Lamp" is the correct term for a light bulb. The fixture that holds the lamp is a *luminaire*. Technically, an ordinary table lamp is a "portable luminaire." There are three main families of light sources and, within these families, hundreds of different lamps. Each lamp produces light in a particular way and emits light of a specific color, quantity, and direction.

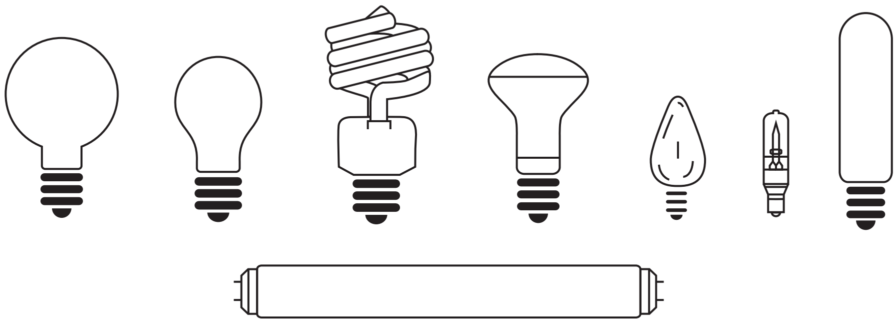


Figure 2-5. *Lamps.* Lamps are available in hundreds of different shapes and sizes.

Most lamps produce light that is white. They emit the three primary colors red, green, and blue, and most, or all, of the other colors. A catchall phrase for these lamps is *general light source*. General light sources provide *ambient light*, which is general area lighting. A lamp that is missing one or more of the primary colors gives off colored light. It is not a general light source. The lamps in neon signs are one example of a light source emitting a narrow range of wavelengths.

Figure 2-6. *Additive Color.* Neon signs are a familiar example of additive color, or color seen as direct light reaching the eye.

All white light sources, however, do not produce white light that is exactly the same. Each type of lamp emits wavelengths in a characteristic pattern called a *spectral distribution curve,* or *spectral reflectance curve*. The spectral distribution curve shows which wavelengths are actually present and the strength of each wavelength relative to the others for that particular type of lamp. The curve provides a visual profile of the color characteristics of any source. A lamp may emit one or two of the primaries at a higher level of energy than the others; or additional colors may be emitted strongly, or one or more may be missing entirely. If each wavelength leaving a lamp is imagined as a colored ribbon, some of the ribbons will be thicker, wider, and stronger than others.

Spectral distribution determines (and describes) the color quality of a light source: whether the light it produces is seen as neutral white ("pure" white, or red, green, and blue equally), warm white (stronger in the yellow-red range), or cool white (stronger in green or blue). Every lamp can be described technically by its spectral distribution. *Differences in spectral distribution determine how different kinds of lamps render (show, or display) the colors of objects*.

To refer to light sources as "true," or "natural," or "artificial," is deceptive. It leads to the misconception that there is "true" light and its opposite, "false" light. We think of natural light (sunlight) and artificial light (from man-made sources) as if they were different entities, but light is always visible energy. There are naturally occurring light sources and man-made ones. Every general light source produces light that can be differentiated from other sources in two ways. The first is by its spectral distribution. The second is by its *apparent* whiteness. Daylight is the standard of whiteness for man-made light sources, and, because response to sunlight is part of our genetic makeup, it also helps to determine whether light from a given source will be sensed as more or less natural.

About 40% of man-made interior lighting is used for domestic purposes.[2] The balance is used to illuminate public and commercial spaces. The most familiar man-made light sources are incandescent and fluorescent lamps. High-intensity discharge (HID) lamps, like the high pressure sodium lamps used in street lamps, or the mercury vapor lamps used as night lighting for ballfields, are also in common use.

Incandescent lamps, like the sun, produce light by burning. The light they emit is a small byproduct of heat—only about 5% of the energy used by an incandescent lamp results in light.

Like the sun, incandescent sources emit the visible wavelengths as a continuous spectrum. Candlelight, firelight, and incandescent lamplight are sensed as comforting because they emit light in the same way the sun does.

The apparent whiteness of an incandescent lamp depends on the temperature at which it burns, called its *color temperature.* Color temperature in lamps is measured in degrees Kelvin (K). A typical incandescent lamp burns at a relatively low temperature, around 2600-3000K. An incandescent lamp typically sheds a warm, yellow light because it gives off more energy in the red-orange-yellow range than in the blue or green. Lamps that burn hotter emit bluer light; very white light is hottest of all. A halogen lamp is a type of incandescent lamp with a gas inside the glass envelope that causes it to burn at a high temperature; as a result the light produced is a bluer white. The heat-light-color relationship is recognized in colloquial language; something that is "white-hot" is dangerously hotter than something "red-hot."

The color temperature of a lamp is used as a measure of whiteness for the color of *light* produced by lamps. *It does not help to predict how a light source will render the colors of objects*. Different lamps reach their color temperature in different ways, and spectral distribution information is not always available. Experienced designers use mockups in field conditions to make sure that the lamps they specify will deliver the right quantity and quality of light for each situation.

Fluorescent lamps produce light in a completely different way. The interior of the glass bulb is coated with phosphors, substances that emit light when they are bombarded with electrical energy. The color of a fluorescent lamp depends on the particular makeup of its phosphor coating. Fluorescent lamps do not burn, so they do not have an actual color temperature, but they are assigned an "apparent color temperature" to indicate their degree of whiteness.

Fluorescent lamps do not produce the continuous spectrum that is characteristic of incandescent light. Instead, they give off light as a series of separate bands of energy. Although fluorescent lamps are available with many different spectral distributions, a typical low-cost fluorescent lamp emits all wavelengths at similar levels of energy. Because of the eye's sensitivity to yellow-green, the white light emitted by an ordinary fluorescent lamp has as yellow-greenish cast.

Whether at home, at work, or at play, the color of light around them affects how people feel about their environment. Light from a source with a continuous spectrum—from a source that imitates sunlight—is sensed as the most comfortable, the most welcoming, and the most natural. Many lamps are marketed as "full-spectrum," as if this were some magical solution to a host of light and color problems. A lamp described by its manufacturer in this way tells the purchaser only that the lamp emits all wavelengths. It does not describe the strength of those wavelengths relative to each other, or tell whether or not the wavelengths are continuous, or describe the relative warm or coolness of the white light that is produced.

Present-day efforts to find environmentally responsible light sources have created an explosion of research into new sources of light. The current focus is on LED lamps, which produce light at low operating cost by combining the output of red, green, and blue light-emitting diodes. The light that results is white, strong, and energy efficient: excellent for limited uses like car headlamps, but problematic as a light source for interior environments because it contains only the three primary colors and does not have a continuous spectrum. LED lamps have been developed that include phosphors to increase their spectrum, but these lamps are not yet perfected, and even at their best will not produce a continuous spectrum. Research is ongoing in the effort to improve the color rendering of LED sources, but at the time of this writing LED lamplight, despite its environmental virtues, is less than ideal in its ability to render the colors of the real world.

Lighting Level

Lighting level refers to the *quantity* of available light, regardless of its color makeup. Lighting level describes the *total* amount of light coming from the source. The amount of light emitted by a lamp is unrelated to its spectral distribution. The same lamp type may give off more or less light, but its spectral distribution—the pattern of relative energy emitted at the different wavelengths—is identical for that lamp type no matter what quantity of light it gives off.

Too little available light makes it hard to see colors. Excessive and uncontrolled light falling on a surface can also impair color perception. *Glare* is an extreme, physically fatiguing level of general light. Glare obliterates color perception and can be temporarily blinding. Glare is corrected by adjusting the light source: by reducing the quantity of light, changing the direction from which it comes, or both.

Reflectance, or *luminance*, is a measure of the amount of light falling on a surface that is reflected *back*. It is a measure of the total amount of light reflected, not the individual wavelengths (colors). Reflectance is so important to some products, like interior and exterior paints, that the percentage of light reflected back from each color, called its LRV (light-reflecting value), is part of the basic information the manufacturer provides.

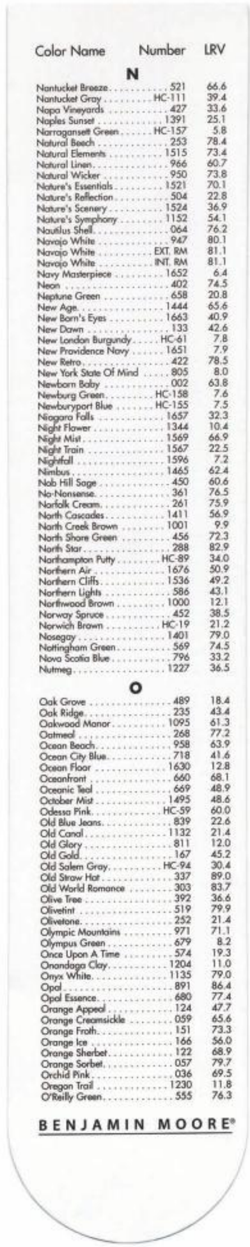


Figure 2-7. Benjamin Moore provides an LRV for each of its paint colors.

Benjamin Moore LRVs are valid only for Benjamin Moore colors tinted by a Benjamin Moore retailer.

The ability to perform most tasks depends on the ability to see the difference between dark and light, not on the ability to detect color. Black-and-white photographs and written text are perfectly understandable. The ability to see dark/light contrast is unaffected by lamp color. Only lighting level affects the ability to see dark and light differences. And although many people report different levels of comfort under a variety of light sources, human performance under general light sources has not been shown to be affected by lamp color, only by lighting levels.[3]

Vision

Vision is the sense that detects the environment and objects in it through the eyes. It is the principal way in which physical realities like objects and the environment are discerned and the only way in which color is perceived.

Color vision is experienced in two different ways: either as light directly from a light source, or as light reflected from an object. In the *illuminant mode of vision,* colors are experienced as direct light reaching the eye, like the colors of a monitor screen or a neon sign. In the *object mode of vision* colors are seen indirectly, as reflected light. The tangible things of the real world—objects and the environment—are seen in the object mode of vision.

The Illuminant Mode of Vision

The *illuminant mode of vision* has two variables in the perception of color: the characteristics of the light source and those of the viewer. Wavelengths of light are measurable and can be established definitively, but each viewer's perception of color is to some extent individual. Viewers with normal color vision will vary slightly in their ability to sense colors, but more significantly, they interpret what they have sensed in different and personal ways. Each person's perception of color is to some extent a singular event.

Television and computer monitor displays, traffic lights, and neon signs are examples of the illuminant mode of vision. Colors seen in the illuminant mode of vision are additive colors. Additive colors are more stable than the colors of objects. Colors of light do not change when a source (like a monitor) is moved from a setting with one type of ambient lighting to a different one, or from darker to lighter surroundings. A measurable wavelength or mixture of wavelengths is constant unless there is a change in the pattern, or the strength, of wavelength emission from its source.

The Object Mode of Vision

In the *object mode of vision,* color is seen as light reflected from a surface. Physical objects and the environment are seen as reflected light. Color perception in the object mode of vision has *three* variables: the characteristics of the light source, the individual viewer's visual acuity for color and interpretation of it, and the light-modifying characteristics of the object. The three are so interdependent that if any one changes, the apparent color of the object will also change.

Light leaving a light source is the *incident beam*. When the incident beam reaches a surface, some or all of the light falling on the surface scatters, or reflects—in other words, bounces off it. The *reflected beam* is light that leaves a surface and reaches the eye.

Colors seen as reflected light are understood differently from colors seen as direct light. A classic misunderstanding of that difference took place in the 1970s when many fire engines were painted yellow-green instead of the traditional red. The apparent reasoning for this was that the sensitivity of the eye to yellow-green light made yellow-green the most visible, and therefore the safest, color. Yellow-green fire engines disappeared very quickly and the traditional red returned, an outcome not of nostalgia but of practical reality. Fire engines are objects, not wavelengths of light. Very different principles of high visibility apply. Red fire engines are more visible than yellow-green ones because red is more likely than yellow-green to contrast sharply with the natural or man-made environment.

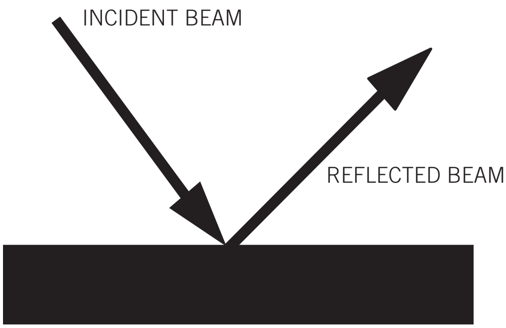


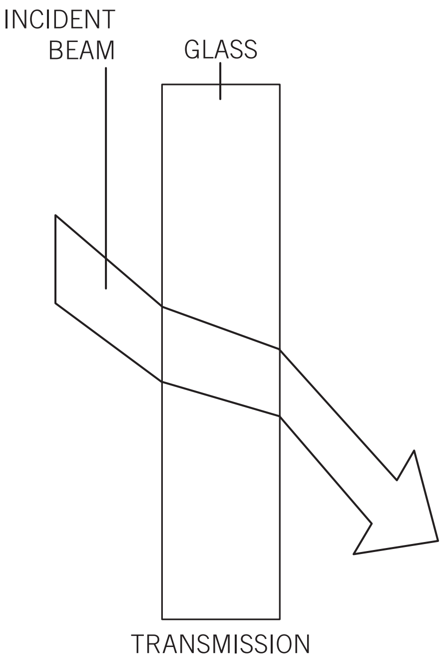
Figure 2-8. *Scattering, or Reflection.* Light reaching a surface is an incident beam. The reflected beam is light that leaves a surface and reaches the eye.

Subtractive Color: Colorants

Materials are the substances of the real world. They are the "stuff" of physical objects, the things that can be seen and touched. *Materials modify light*. Light reaching a material is modified in one of three ways:

> *Transmission*: the material allows light to pass through, as through glass.
>
> *Absorption*: the material soaks up light reaching it like a sponge, and the light is lost as visible. It can no longer be seen.
>
> *Reflection,* or *scattering*: light reaching a material bounces off it, changing direction.

Colorants are special materials that modify light by *absorbing* some wavelengths and *reflecting* others. There are natural colorants, like chlorophyll, the green of plants, and hemoglobin, the red of blood. Manufactured colorants for products and print are derived from a wide variety of natural and synthetic substances. A colorant can be integrated into the substance of a material, like a color-through plastic, or applied to a surface as a coating. Colorants are also called color agents, dyes, pigments, and dyestuffs, depending on their makeup or end use.



A white colorant reflects, or scatters, all wavelengths of light. A white object placed under a general light source reflects all of the wavelengths reaching it, and all (or most) of that reflected light reaches the eye. A black colorant *absorbs* all of the wavelengths of light. An black object placed under a general light source absorbs all wavelengths of light reaching it, and none (or very little) is reflected back to the eye.

Other colorants modify light *selectively.* A red colorant absorbs all of the wavelengths except the red. An object with a red colorant that is placed under a general light source absorbs all of the wavelengths of light reaching it except the red, which it reflects. Only the red wavelength reaches the eye, and the object is understood to be red.

Figure 2-9.
Transmission. Window glass transmits light, allowing it to pass through with no perceptible change. Thin glass bends light so slightly that it retains its whiteness.

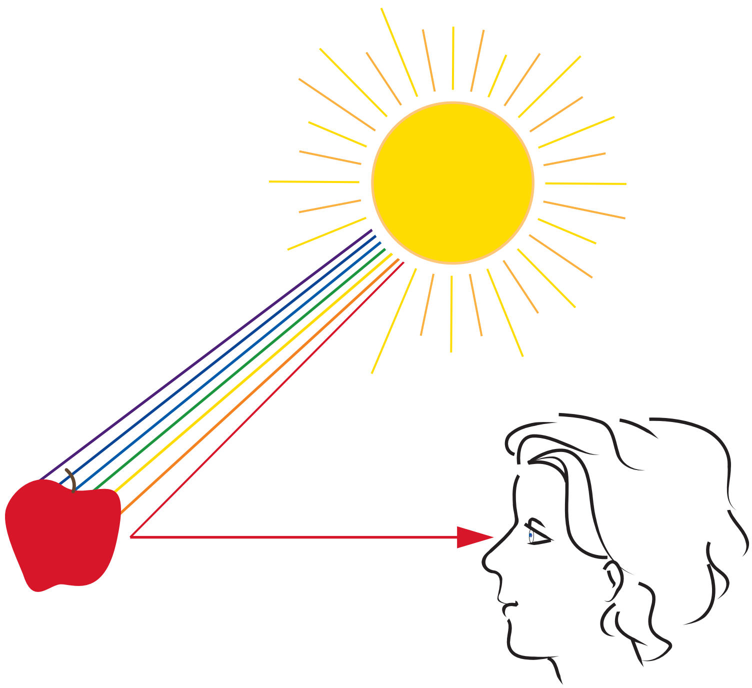


Figure 2-10.
Subtractive Color. The colorant of a red apple absorbs all the wavelengths except red. Only the reflected (red) wavelength reaches the eye, and the apple is seen as red.

In order for an object to be seen as a color, the wavelengths that its colorant reflects must be present in the light source. If a red object is placed under a source that lacks the red wavelength, all wavelengths reaching the object will absorbed. There is no red wavelength present to be reflected back to the eye. A red dress seen under green light is a black dress. In a parking lot illuminated by the light of yellow sodium lamps, red cars, green cars, and blue cars are indistinguishable from each other. Only yellow cars can be located by their color.

Colorants don't absorb and reflect individual wavelengths perfectly. They may absorb part of a wavelength and reflect part of it, or reflect more than one wavelength. So many possibilities exist that the range of visible colors is nearly infinite. Colors seen as the result of the absorption of light are *subtractive mixtures.* Colorants "subtract," or absorb, some wavelengths. The remaining wavelengths are reflected and reach the eye as color.

Lamps are compared by the power of emission at each wavelength. Colorants are compared by their ability to reflect each wavelength. An accurate comparison between color samples can be made only when the samples are compared under the same light source. The light source frequently used for critical color comparisons in a laboratory setting is a Macbeth lamp, which has spectral distribution similar to sunlight. One sample is designated as a *standard* and others are measured against it under the Macbeth lamp. The ability to measure color under controlled laboratory conditions has little practical application for the artist or designer, but it is important for quality control in manufacturing.

It is a common misconception that the "true color" of any object can be captured under the correct lamp. Among the most familiar light sources are A-lamps, or ordinary incandescent light bulbs, and cool fluorescent tubes. Each is different in spectral reflectance from the sun, from the Macbeth lamp, and from each other. A Macbeth lamp is a laboratory tool, not a readily available general light source. If true colors of materials existed, and were visible only under Macbeth lamps or in sunlight, they would be seen only in lighting laboratories and in the outdoors. Science can designate true colors of light as measurable wavelengths, but the concept that there are "true colors" of material objects is misleading. The color of an object is only as true as each viewer chooses to think of it.

Lamps and Color Rendition

General light sources vary widely in the way that they render the colors of objects. The same object will change in color under a variety of light sources because of differences in the spectral reflectance of each source.

Making color choices under one set of lighting conditions for use under a different set of lighting conditions can be a disaster. A woman wearing astonishingly bright red makeup has probably applied her cosmetics under standard fluorescent lighting. These lamps emit a relatively low level of red wavelength, so items with red colorants receive little red light to reflect. One way to compensate for this is to increase the amount of colorant—rouge or lipstick—to get a visibly red result under the fluorescent source. In daylight or incandescent light, the red is overwhelming.

Fluorescent lamps are the current standard for use in commercial applications. They provide high light output and low heat at reasonable operating cost, but vendors are aware of the weak spot in the color rendition of standard fluorescents. Grocers choose lamps with a stronger red component for use over meat counters to ensure that products appear fresh and healthy. High-end cosmetics counters provide separate light sources for sampling colors.

In residential interior design, considerations of color rendition usually take precedence over operating cost. Incandescent lamps are nearly always chosen over fluorescents as a general source. Lamps can be selected to enhance color schemes. Some manufacturers recommend specific lamps for different situations: one type for warm color schemes, another for cool ones. Conversely, lamps can be used to make color adjustments or corrections in completed interiors. Colors selected in daylight may be too warm or too cool for night lighting. Red-orange schemes can be muted by using a lamp with a weaker warm range; color schemes that are too blue or green can be muted by using lamps with stronger output in the red-orange-yellow range.

The near-universal specification of fluorescent lamping for commercial applications, including such crucial areas as studio work spaces, is often made without consideration of color rendering qualities. The poor color rendering that results from poor lamp choice remains problematic for designers, manufacturers, retailers, and consumers because for most products, from foods and flowers to cosmetics and carpets, good color presentation is critical to sales.

Metamerism and Matching

Two objects that appear to match under one light source but not under another exhibit *metamerism*. The objects are called a *metameric pair*.

Materials differ in their ability to absorb colorants or accept them as coatings. The substance used as a blue colorant for wool may have little or no chemical relationship to one used to produce a similar blue in cotton. Still other substances are blue colorants for plastics, glass, paint, or ceramic dinnerware. Each colorant reacts to light in a very specific way. If the colorants of two things are different, they cannot be made to match under all light conditions. The underlying material, or substrate, can also at times influence color rendition.

Two red-dyed cottons may appear to match exactly under incandescent lighting. If their dyes are different, one may actually be more red-reflective than the other. When the two are placed under a fluorescent lamp (that is weaker in the red wavelength), the cotton with the more red-reflective dye appears brighter and “redder” than the other.

So-called “matching” wallpapers and fabrics, or silk shirts and wool skirts, or china sinks and enameled cast iron bathtubs, can never truly match because both their underlying materials and colorants are different. What is possible and practical is to reach an *acceptable match*, one that is pleasing to the eye. When different materials must reach an acceptable match, it is essential to compare them under lighting conditions that duplicate their end placement.

Some manufacturers and vendors control acceptable match in related goods by maintaining color laboratories. Sears is known for its care in ensuring that home products are color-compatible. A refrigerator purchased in Sears “Bisque” is likely to be an acceptable match to Sears “Bisque” dish towels or pots, and both are likely to be compatible with other nationally distributed products, like Wilsonart laminates, with the same color name.

Maintaining a laboratory for color and light problems is not realistic or necessary for graphic, textile, fashion, or interior designers, architects, small-scale manufacturers, or product designers. General Electric suggests that any pair of objects reaching acceptable match under both fluorescent and incandescent lamps will be acceptable under nearly all conditions.[4] This practical advice covers almost all color-compatibility situations, as long as the real limitations of color matching between two different materials are understood.

A sample submitted for color matching is a *standard*. There are times when the match to a standard must be stable under all light conditions. In order for this to happen, the new goods must be made of the same substrate (base material) and the same colorant used as in the original. A match that is perfect under any light conditions is possible only when the original standard and the new product are identical in all ways.

Only manufacturers who control the complete production and color process can offer perfect matches to a standard. But throughout the process and at its conclusion, the match is judged not only by laboratory testing but by the dyer, the designer, the manufacturer or the client: *ultimately*, *by human eyes alone*.

Modifying Light: Surface

Surface is the outermost layer of a thing, its "skin." Different surfaces—rough, smooth, or in between—have an impact on the way that colors are perceived. The word *value* refers to the relative lightness or darkness of a hue. *Only the perception of value is affected by surface texture*. Smooth surfaces reflect light very directly, so that a good deal of light reaches the eyes. Rough surfaces scatter light in many directions, and less light reaches the eyes. Surface texture has no effect on hue. A rough-skinned object and a smooth one that have the same colorant will be identical in hue under any kind of illumination, but the first will appear darker, the second lighter.

Light striking a surface reflects, or bounces off it. The position of a surface relative to the light source determines the angle at which the incident beam reaches it. The light that bounces off the surface, the reflected beam, does so at exactly the same angle as it reached it. This is the law of reflection: the angle of the incident beam determines the direction of the reflected beam.

The smoother the surface, the greater the amount of light that is reflected back directly. A *specular* surface is glossy, or mirror-like. Light leaving a specular surface is reflected so immediately, and so directionally, that most (or all) of it is seen as white light. When a specular surface is viewed from the *same* angle as the incident beam, only white light is seen: a specular reflection. When a specular surface is viewed from an angle that is *not* the same as the angle of the incident beam, some light reaching the underlying colorant can be seen. The surface still dazzles with white light, but color is seen as well—although darkened, because so much light has been deflected before reaching the colorant. The extreme reflectance of specular surfaces makes it difficult to interpret their color no matter what the viewing angle. Sequined garments are a perfect example: each sequin flashes with white light until the wearer moves and changes the viewing angle, when its color becomes suddenly, briefly, visible.

A *matte* surface is a smooth surface that is very slightly, even microscopically, roughened. Its roughness is too fine to be seen with the naked eye. A matte surface diffuses (spreads) light very evenly in many directions, so that light leaving the surface is constant from any angle of view. Colors on a matte surface, like an uncoated paper, have a flatness and uniformity under nearly all lighting conditions.

Textured surfaces are dynamic and lively. When incident light reaches a surface that has peaks and valleys of different orientations, the beams of light follow the law of reflection. Light scatters in random directions, dappling the surface with patches of light and shadow.

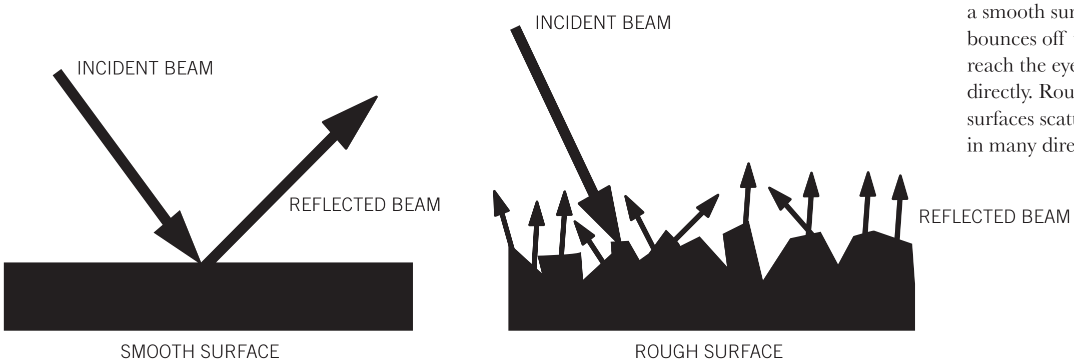


Figure 2-11.
Rough and Smooth. Light reaching a smooth surface bounces off to reach the eye very directly. Rougher surfaces scatter light in many directions.

Texture is most apparent under point light sources, like sunlight or incandescent lamps. Light from a point source originates from a single location, or point, and the beams of light emitted are parallel. Fluorescent lamps are linear light sources. Linear light sources emit a broad-spread light in that is essentially non-directional. Light from a linear source does not reach the surface at an angle in the same way as a point light source. Reflected beams are less directional, so shadows are reduced or even absent. Even heavily textured surfaces tend to appear flat and uniform under fluorescent (or other linear) lighting. LED lamps are currently offered as both linear and point sources, but LED lamps are an emerging technology and their rendition of color and surface is difficult to evaluate at this time.

Figure 2-12.
Texture. Pattern can be created with yarn of only one color when it is woven as looped in some areas and as cut ends in others. *Image of carpet "Ardennes" courtesy of Edward Fields Carpet Makers.*

The sharper the angle of incident light, the more directional the reflected beam will be. *Raking light* describes light from a source that is positioned at an acute angle relative to a surface. Specular surfaces appear more glossy, and textured surfaces dramatically rougher, under raking light.

No matter what the ambient light, varying the textures of a surface allows designers to create an effect of two or more colors (or more accurately, lighter and darker variants of a single hue) using only one material. A piece of yarn, seen on its long side, is relatively smooth. Cut ends of the same yarn (a pile, or nap) reflect the identical wavelength but scatter light more widely and appear darker. Textiles made of a single yarn can be woven into intricate patterns by alternating areas of flat weave with areas of cut pile, or by contrasting them against areas of textured weave. Embossed metals and "frosted" glassware are other examples of surfaces that have been manipulated to create dark and light patterning within a single material and color.

Transparent, Opaque, and Translucent

A small amount of light is lost each time that light travels from a source to a surface and, when light reaches a surface, a very small amount reflects back immediately. The sum of this light loss can be so slight that as a practical matter it is unimportant. The light that remains is reflected, absorbed, transmitted, or a combination of these. If all of the light reaching an object is either reflected or absorbed, the object is *opaque*. If all (or nearly all) of the light reaching an object or material is transmitted, that object is *transparent*. Window glass is an example of transparent material.

When some of the light reaching an object or material is transmitted and some is reflected, the object is *translucent*. A translucent material can be white or a color, depending on its selective transmission and reflection of the various wavelengths. Translucent materials may allow a great deal of light to pass through (and be very translucent) or transmit very little light (and be barely translucent).

The terms “translucent” and “transparent” often are used interchangeably, but they do not mean the same thing. A truly transparent material is like window glass: for all practical purposes, it is invisible. A translucent material is detectably present, no matter how sheer it may be.

Iridescence

Iridescence is a attribute of surfaces on which the hue changes as the observer’s angle of view changes. The changes from blue to green that are seen in a butterfly’s wing as it flies, or the flashes of red, purple, and green in the black feathers of a grackle, or the brilliant and changing colors of soap bubbles and oil films are iridescence.

Iridescence is an optical phenomenon that occurs with reflected light. The color is produced by the structure of a surface that amplifies some wavelengths of light and suppresses others, depending on the angle of the light reaching it. The amplification of light makes iridescent color extremely vivid—the color that reaches the eyes may be reflected, but in the absence of a modifying colorant it is sensed as pure light. Because no colorant is involved—nothing that absorbs some wavelengths of light and reflects others—it is sometimes called structural color.

Iridescent textiles are brilliantly shimmery, seeming to be one color at one angle of view and a second color as the fabric moves. Iridescence in textiles is produced in a variety of ways. There are silk yarns with a molecular structure that creates iridescence, as well as synthetic yarns with similar properties. Most iridescent textiles, however, are made using special yarns and techniques of weaving. When the warp and filling are made from differently colored and light-reflective yarns; each color appears, vanishes, and reappears as the viewing angle shifts.

There are paints and inks with light-reflecting properties that create convincing iridescent effects on a page. As the observer's position changes, the color changes. An impression of iridescence is difficult to create on a screen, because light leaving a screen reaches the eye directly, no matter what the viewer's position or movements.

Luminosity

Luminosity is a word that appears often in color study. Its real meaning is the attribute of emitting light without heat. A luminous object is light-reflective, but it does not emit heat. The word luminous is used often to describe very light-reflecting colors and media with a great deal of light reflectance, like watercolor, dyes, or markers.

Indirect Light, Indirect Color

Indirect light occurs when light from a light source reaches a broad, light reflective plane that re-reflects it onto a second surface or object. In order for this to happen, the light source, the reflective surface, and the target surface or object must be positioned at similar angles to one another. Moonlight is a familiar form of indirect light. The moon is luminous: it reflects light but does not emit its own energy. Its surface reflects the light of the sun to the earth.

Each time light travels, some of it is lost through scattering. Moonlight is weaker than sunlight because much of the sun's light has been scattered and lost, first on its way from the sun to the moon, then again from the moon to the earth. Indirect lighting works in the same way as moonlight does. Light reaching a white surface is redirected to a target area. The indirectly lit area appears darker than it would under direct light, but no change in its apparent hue takes place.

Indirect *color* is a form of indirect light. Indirect color occurs when general light reaches a highly reflective color on a broad plane. Some of the general light—and a good deal of the strong color—will reflect onto any surface that is positioned to receive it.

Imagine sunlight reaching a wall that is covered with a highly reflective green paint. The green surface absorbs all wavelengths except the green, which is scattered onto a nearby chicken. If the chicken has white feathers, its surface reflects the green wavelength and the chicken appear to be green. If the chicken has red feathers, the green reaching it is a absorbed and the chicken appears to be a darker and duller red.

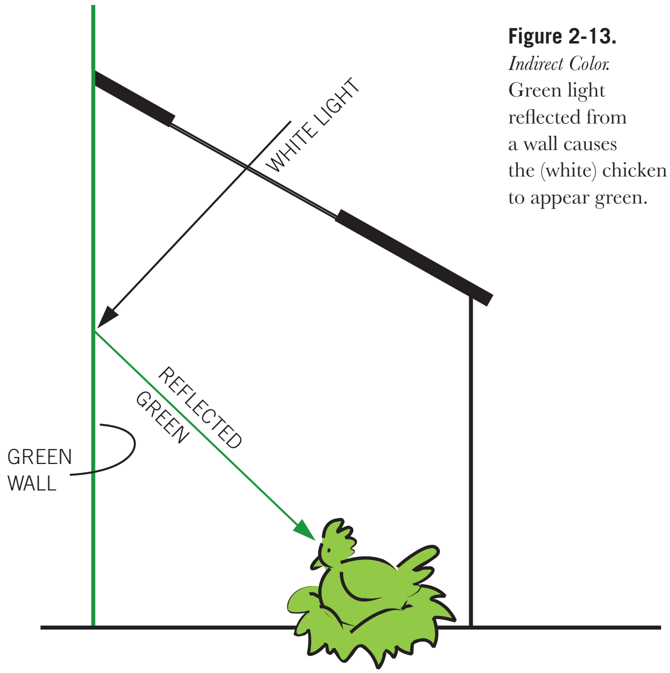


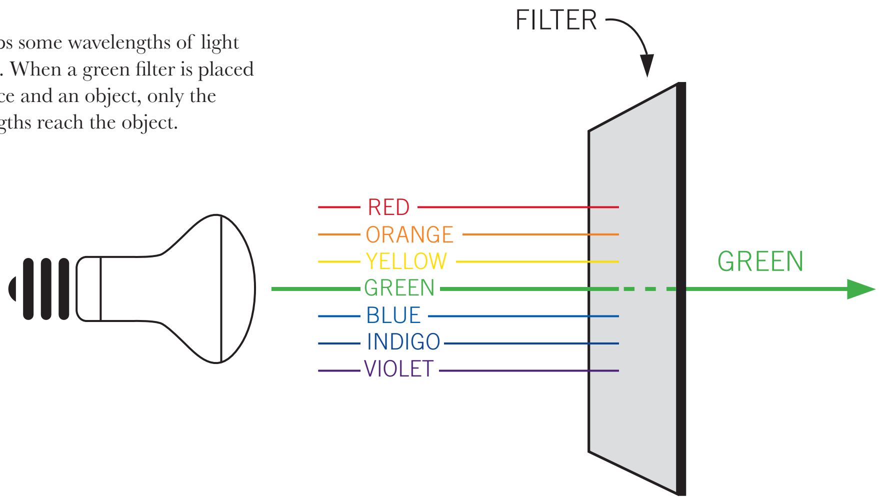
Figure 2-13.
Indirect Color.
Green light reflected from a wall causes the (white) chicken to appear green.

One way to describe the phenomenon of color reflected from one surface to another is *plane reflection.* The design applications most vulnerable to this are architecture and interior design, where planes of color on walls, floors, and ceilings interact with directional light sources to create potential conditions of light and color reflection. Although the strength of indirect color is diluted by scattered general light from the original source, plane reflection can cause substantial—and unexpected—distortions in architectural and interior design color programs.

Modifying Light: Filters

Filters are materials that transmit (pass through) some wavelengths of light and absorb others. A red filter placed between a light source and an object allows only the red wavelengths to pass through. Other wavelengths are absorbed. An object with a red colorant, seen through the filter, appears red. An object with a white colorant also appears red because a white

Figure 2-14.
Filters. A filter absorbs some wavelengths of light and transmits others. When a green filter is placed between a light source and an object, only the transmitted wavelengths reach the object.



surface reflects any wavelength reaching it. If the object reflects a color other than white or red, it will appear black (or near-black). The red filter transmits only the red wavelength. No other wavelength reaches the object, so none can be reflected back.

Filters are powerful modifiers of light, so they must be used with real understanding of their effects. *The New York Times* once published the story of a restaurateur who wanted to create a romantic atmosphere by bathing his establishment in warm, rose-red light. Instead of using lamps with a strong red wavelength (which would have provided a rosy white light, but allowed all colors to be seen), he installed red theatrical gels (filters), which blocked all the wavelengths except red. The gels were extremely effective: the vegetables and salads that arrived at the tables were black.

Endnotes

1 http://www.bway.net/-jscruggs/add..html
2 Fedstats/USA.gov/Department of Energy
3 General Electric Lighting Application Bulletin #205-42311.
4 Ibid.

Chapter 2 Highlights

- Only light generates color. Light is visible energy that is emitted by a light source. Light sources emit this energy in waves at different distances apart, or frequencies. Each wave is perceived as a separate color. The human eye is a sense organ that is adapted to receive wavelengths of light within a narrow range called the visible spectrum.

- White light is produced when a source emits red, green, and blue wavelengths in roughly equal proportions. Red, green, and blue are the primary colors of light. Cyan, magenta, and yellow are the secondary colors of light. Blue and green wavelengths combined produce cyan. Red and blue wavelengths combined produce magenta and green and red wavelengths combined produce yellow. White or colored light seen as a result of a combination of wavelengths is called an additive mixture or additive color.

- Sunlight is made up of all visible wavelengths emitted in a continuous band. Light emitted in a continuous band is sensed as the most natural. Lamps are the principal man-made light sources. Each type of lamp emits wavelengths in a pattern, or spectral reflectance (or distribution) curve, that shows which wavelengths are present and the strength of each relative to the others for that type of lamp. Differences in spectral distribution determine how different kinds of lamps render the colors of objects. A lamp marketed as "full-spectrum," does not tell the purchaser the strength of the wavelengths relative to each other or whether they are continuous.

- Incandescent lamps produce light by burning. The whiteness of an incandescent lamp depends on the temperature at which it burns, or color temperature. Fluorescent lamps contain phosphors that emit light when they are bombarded with electrical energy. The color of a fluorescent lamp depends on the makeup of its phosphor coating. Fluorescent lamps do not produce light as a continuous band. Present-day efforts to find environmentally responsible light sources are focused on LED lamps, which produce white light by combining the output of red, green, and blue light-emitting diodes.

- Lighting level refers to the quantity of available light, regardless of its color makeup. Reflectance, or luminance, is a measure of the amount of light falling on a surface that is reflected back. The ability to perform most tasks depends on the ability to see the difference between dark and light, not on the ability to detect color.

- Colors are seen in one of two ways. The illuminant mode of vision has two variables: a light source and a viewer. Colors seen in the illuminant mode of vision are seen as direct light and are called additive colors. The object mode of vision has three variables: the light source, the viewer, and the light-modifying characteristics of an object. Colors in the object mode of vision are seen as light reflected from a surface material and are called subtractive colors.

- Materials are substances that modify light by transmission, by absorption, or by reflection. Colorants are materials that modify light selectively by absorbing some wavelengths and reflecting others. Colors seen as the result of the absorption and reflection of light are subtractive colors.

- If all light reaching a surface is transmitted, the object is transparent. If all light reaching a surface is reflected or absorbed, the object is opaque. If some of the light reaching a surface is transmitted and some is reflected, the object is translucent.

- In order for an object to be seen as a color, the wavelengths that its colorant reflects must be present in the light source. A true comparison between color samples can be made only when they are compared under the same light source. Two objects that appear to match under one light source but do not match under another are called a metameric pair.

- Light bounces off a surface at the same angle as it reaches it. A matte surface spreads light evenly, so that light leaving it is constant from any angle of view. Light reaching a surface that has peaks and valleys of different orientations scatters light in random directions, resulting in patterns of light and shadow, or texture.

- Iridescence is a attribute of surfaces on which the hue changes as the observer's angle of view changes. Indirect color occurs when general light reaches a highly reflective color on a broad plane. Both general and colored light are then re-reflected onto any surface positioned at the correct angle to receive them.

3 THE HUMAN ELEMENT

The Sensation of Color / Threshold / Intervals / The Perception of Color / Physiology: Responding to Light / Healing and Color / Synaesthesia / Psychology: Responding to Light / Naming Colors / Color as Language: From Name to Meaning / Impressional Color / Color as Words Alone

Color responses are more tied to man's emotions than to his intellect. In general, people do not respond to color with their minds.

—Deborah Sharpe

Of all the senses that connect us to the world—vision, hearing, taste, smell, and touch—vision is the most important. More than 80% of our sensory experiences are visual. We are drawn to light, and to color.

The instrument used in solving color problems in the design studio is the normal, unaided, human eye. For artists and designers, dyers and house painters, printers and carpet sellers, even when aided by tools of color technology, final decisions about color are made by human eyes alone.

The Sensation of Color

The experience of color begins with a *sensation.* A sensation is an actual, physical event. It is the body's response to a *stimulus*, something that is encountered from the outside world. Light, which is visible energy, is the stimulus for the sensation of sight. A stimulus is measurable: the color and quantity of light emitted by a light source can be measured.

Sensations are also measurable. An individual's ability to detect light is measured as *visual acuity*, or sharpness of vision. Visual acuity is the ability to sense patterns of light and dark and to resolve detail. It is a measure of the weakest light stimulus that an individual can detect. The ability to see differences between dark and light is not the same as visual acuity for color. Someone who can discriminate very small differences between a dark gray and a slightly lighter one may not be able to detect a difference between two reds, one of which is slightly more red-violet than the other.

Figure 3-1.
Visual Acuity. Small differences between dark and light may be difficult for some people to see. Others with greater visual acuity can see a difference between very similar grays.

Visual acuity for *color* is the ability to detect differences between wavelengths (colors) of light. The strength and wavelength of each color of light can be separately measured using scientific instruments, but human beings do not see the spectrum as a progression of individual colors. The spectrum of light is sensed as a flowing and unbroken continuum, with each color blending into the next like a rainbow.

Color vision enables a viewer to discriminate small differences between hues in this continuous band, like the difference between a red and a red-orange, or a blue and a blue-violet. The human being is said to be able to distinguish about 150 individual colors (hues) of light, although this number is not scientifically established fact. It makes no difference whether the colors are seen as light directly from a light source or as light reflected from a surface. This number does not include the darker, lighter, or duller variations of each color. The multiples of the 150 colors with their variations mean that a person with normal color vision can distinguish millions of different colors.

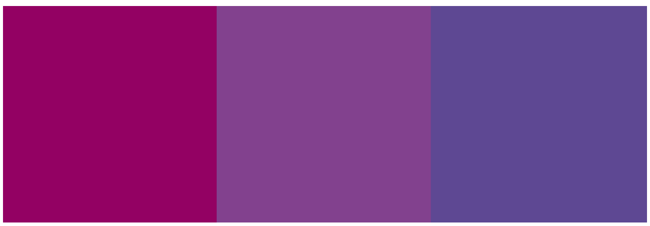


Figure 3-2.
Visual Acuity for Color. Visual acuity for color is the ability to detect differences between similar hues.

Threshold

The *threshold* of vision is the point at which an individual can no longer detect a difference between two close samples. The threshold of *color* vision is the point at which a difference between two similar *hues* can no longer be discriminated. Individuals with normal color vision vary in the threshold of color acuity just as much as they do in their ability to see detail. Each person's vision is modified by factors like individual physiology, health, and age. Infants are believed to be able to detect differences between dark and light before they can see hue, and many older people experience a progressive loss of the ability to discriminate between blues, greens, and violets; thought to be caused by a gradual yellowing of the lens of the eye over time.

Intervals

One way to characterize differences between color samples is in *intervals*. An interval is a step of change between visual sensations. An individual's threshold establishes the *single interval:* the point at which a detectable middle step can no longer be inserted between two close colors. Single intervals take concentrated effort to see and are tiring to the eyes, but they play an important role in many special effects and illusions.

Many design situations call for intervals between three or more elements. *Parent-descendant color mixtures* are a fundamental interval relationship. They are illustrated as three colors arranged in a linear series, with a "parent" at each end and the "descendant," a middle step between the two, centered between them. *Parent-descendant color mixtures are the basis of many special effects and illusions and play a major role in color harmony.*

Figure 3-3. *Parent-Descendent Color Mixtures.* A middle interval can be established between any two parent colors, no matter how different.

Parent-descendant mixtures can be set up between colors having only hue difference, like red and blue; only value difference, like black and white; or only difference in saturation, like brilliant blue and gray-blue. Intervals can also be set up between color samples that contrast in more than one quality. A brilliant red-violet and a tint of gray-green have hue, value, and saturation contrast, but a middle step can still be found between them.

Even intervals occur when the middle step is *visually equidistant* between the two parents. Representative sets of even intervals might be black on one side, white on the other, and middle gray between them, or red on one side, yellow on the other, and orange between them. The important thing about even intervals is that the midpoint be just that: no more like one parent than the other.

Figure 3-4.

Even Intervals of Hue.

Even Intervals of Value.

Even Intervals of Saturation.

Intervals are not limited to the three steps of parent-descendant color mixtures. In a *series* of even intervals, each step is the visual midpoint between the samples on either side of it.

Figure 3-5.
Even Intervals in Series.

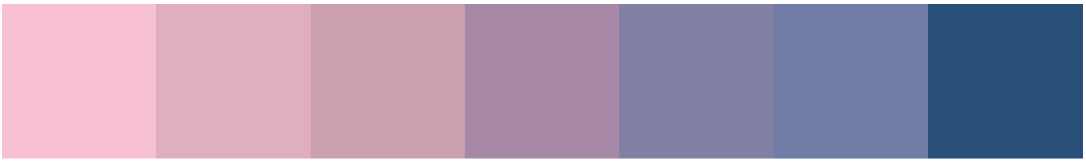


Figure 3-6.
Even and Uneven Intervals of Hue. In the upper set of squares, the center is the middle step between the two parents. In the lower sets of squares, the center is closer to one parent than the other. Do you agree?

Parent-descendant color mixtures occur so frequently in color study that the word "interval" alone is often taken to mean an equidistant step, but intervals can also be uneven. Tilting a middle color deliberately closer to one parent than the other is another technique used in creating special effects and illusions.

Creating order out of random information is a fundamental function of human intelligence. Things are categorized in order to control and understand the flow of information: large to small, A to Z, ascending numbers, dates,

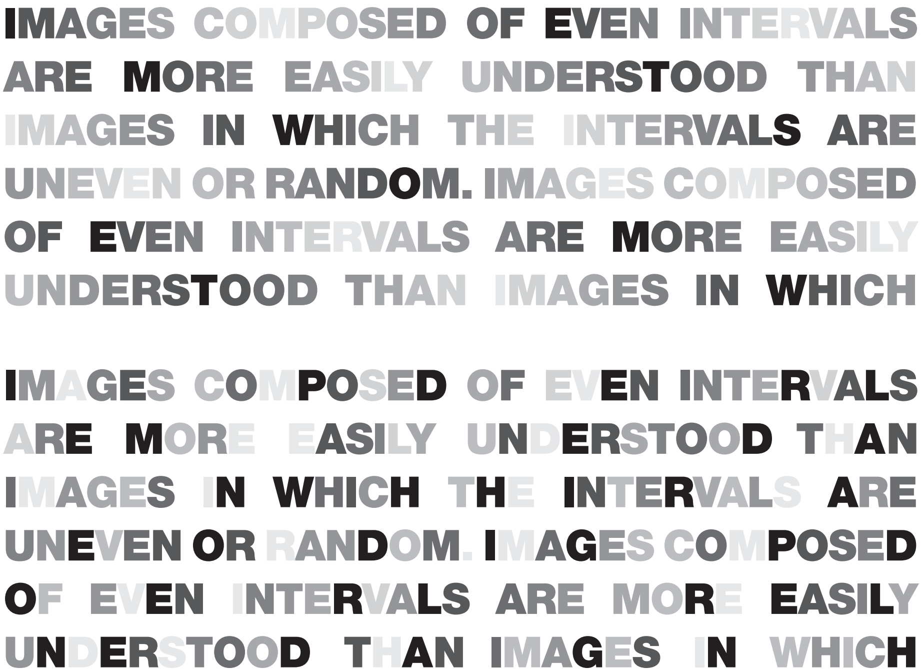


Figure 3-7. *Even and Uneven Intervals.* Images composed of even intervals are more quickly and easily understood than images in which intervals are uneven or random.

or sizes. Orderly information is easier for the brain to process; chaotic information is more difficult. Even intervals are orderly. They are easy for the eye and brain to process. Images composed of even intervals are more quickly and easily understood than images in which intervals are uneven or random.

Intervals are *visually logical* mixes. They are judged by eye alone. Members of a group rarely arrive at complete agreement as to the exact midpoint between two samples. The disagreement is about nuance, not about great differences, and can be attributed to individual differences in visual acuity and interpretation. A perfect interval, like perfect weather, is an opinion that includes a generous portion of fact.

A *gradient* is a series of progressive, even intervals so close that individual steps cannot be distinguished. It is a seamless transition between differences, whether from light to dark, or from one hue to another, or from a brilliant color to a dull one. Shading, for example, is a gradient of values, a "wash" of color from dark to light.

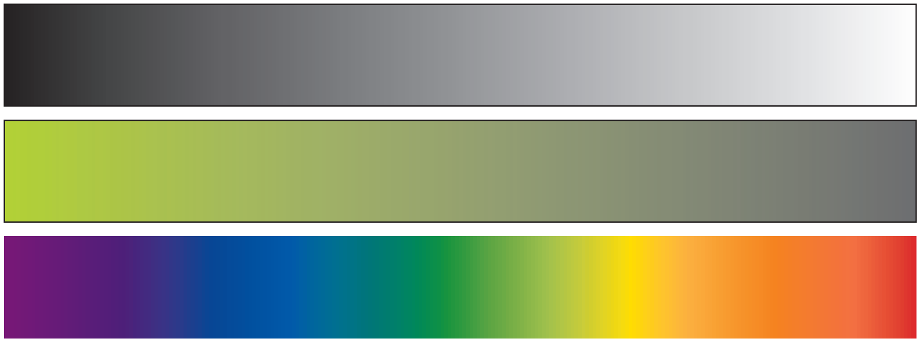


Figure 3-8.
Gradients. A gradient is a progression of intervals in steps of change that are smaller than the human eye can distinguish. The transition can be in hue, value, saturation, or a combination of qualities.

The Perception of Color

A sensation alone—a touch, taste, smell, sight, or sound—is an incomplete event. The occurrence of a sensation is immediately followed by *perception.* Perception is the critical connection between human beings and their environment. It is cognitive, or *knowing*—the understanding and awareness of what has been sensed. Perception *decides* what has been sensed. It *recognizes* and *identifies* the sensation. It acts as a filter, separating useful and important information from competing stimuli in the environment.

When the brain receives a light stimulus it first interprets form as distinct from background by sensing patterns of light and dark. *Figure-ground separation*, or *pattern recognition*, is the first cognitive step in the process of perception. It identifies situations by forms and their arrangement.

Color plays an important, but secondary, role in recognition. A red file folder (unpaid bills) and a blue file folder (paid bills) seem at first to be identified by color. But both red and blue folders are identified first as file folders, and only secondly by color. The initial recognition is of form: this is a file folder, not a notepad, not a CD, not a book.

Recognition is based on learned information from a multitude of sources: individual experience, social and cultural traditions, environmental surroundings, formal teaching. The ability to recognize sensations develops with astonishing rapidity, beginning almost at birth. By adulthood, human beings have acquired and stored an immense database of recognized sensations. Everything seen is understood because its identity has been learned and the experience of it held in memory. New sensations, unless they are accompanied by additional information, are identified by referring to this stored information. Something new is recognized, correctly or incorrectly, because it is associated with some familiar thing that has similar characteristics.

Most perceptions occur unconsciously and at such high speed that they seem simultaneous with sensation.[1] What we think of as the sensory experience of color is always a fusion of sensation and perception. Unlike a sensation, *a perception cannot be measured. It can only be described.*

Understanding how we see, and how we process and respond to what we see, translates directly into design applications. A working knowledge of the fundamentals of perception provides information that helps the designer to direct, even at times to control, the way a design is received by its target audience. Physiology studies the body and its functioning. It is a measurable science that can quantify the body's physical responses to a stimulus of color. Psychology studies behavior; or how organisms perceive and react to situations when they are stimulated in different ways. Psychology can describe—but cannot precisely measure—the ways in which human beings recognize, interpret, and respond to the stimulus of color. Psychology deals with perception.

Physiology: Responding to Light

The nervous system is an information pathway from the outside world to the brain. It is made up of three kinds of cells: receptor cells, transmitter cells, and brain cells. Receptor cells receive information from the outside world (stimuli) and change it into a form of electrical energy that the brain can use. Transmitter cells carry these signals to the brain. Signals from each sense are received in separate, specific locations in the brain. The brain decodes each sensory event first by identifying which sense has been stimulated, then discriminates specific qualities within that sense. In music, for example, it discriminates between notes; in vision, red from blue. Processing the information and generating a response to it is the final step.

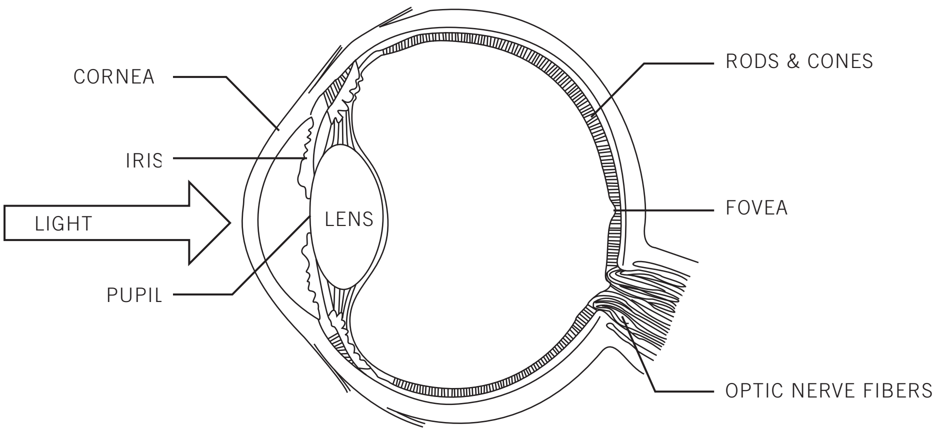


Figure 3-9.
The Human Eye.

The eye is a sense organ that detects light. Light enters the eye through the pupil and falls on the retina, the inside back of the eye. The retina is made up of two kinds of light-sensitive receptor cells, *rods* and *cones*. Both rods and cones connect to the optic nerve, which transmits the sensory message to the brain.

Rods and cones respond selectively to available light. Cones dominate vision when a great deal of light is present. Cones are responsible for color vision and for the ability to see detail. Objects appear more colorful and fine detail, like small print, is clearer when cones are dominant. Rods dominate vision in low light. Rods are responsible for peripheral (surrounding, less focused) vision. Colors appear muted, and fine detail is more difficult to see, when rods dominate.

The *visual field* is the extent of area that can be seen by the two eyes of a viewer standing in one position. The *fovea* is a tiny area at the back of the eye that is the center of the visual field. The fovea contains only cones. It is the most sensitive area of the retina, detecting patterns of light and dark and color with the greatest clarity. Images and colors are seen less clearly when the light stimulus moves away from the fovea.

Both rods and cones are always at work. It is almost as if there are two separate systems, one for day and one for night. *Adaptation* is the involuntary response of the eye to the quantity of available light. The retina moves back and forth (adapts) quickly between rod and cone dominance as the amount of available light increases or decreases. Objects appear more colorful at higher lighting levels, when cones dominate. Color perception lessens in dim light when rods dominate: perception in low light is in shades of gray. A garden that is colorful by day loses its color gradually toward evening, but the contrast of dark foliage and light flowers persists as a different, but equally pleasing, image. Adaptation takes place under any lighting conditions. "Cones for color, rods for gray tones" is the same for sunlight or lamplight, fluorescent, incandescent, or any other kind of light. The sly old metaphor is literally true: all cats really *are* gray in the dark.

Lateral inhibition is an aspect of vision that increases the eye's ability to distinguish edges. When a pattern of light and dark contrast reaches the retina, the cells that receive the light part of the image inhibit the ability of the ones next to them to detect light. As a result, areas next to bright spots appear darker. The greater the quantity of light, the more lateral inhibition takes place: light areas appear lighter and dark areas darker.

The sensation of light is received in two areas of the brain: the cerebral cortex and the hypothalamus, or midbrain. The cerebral cortex is the center of cognitive activity. It receives information and processes it; recognizing, interpreting, and structuring a response to each stimulus. The midbrain controls the internal environment of the body. Sensations of light transmitted to the midbrain act as a biological stimulus to the central nervous system. The midbrain contains the center for regulation of blood pressure and body temperature. It also stimulates glands that control the production and release of hormones. When the brain is stimulated by a thought, mental image, or outside stimulus (like light), the midbrain triggers the release of hormones. A color stimulus has an effect on the strongest human needs and emotions—stress, hunger, thirst, and sex.

Sunlight, which contains all colors, is essential to human life. The human body is genetically adapted to function at a normal level in response to the sun's pattern of energy emission. Changing the strength of a color stimulus causes a change in the body. Exposure to an elevated level of red stimulates hormone production and raises blood pressure, while exposure to an elevated level of blue has been shown to lower blood pressure and depress hormonal secretions.

The immediate biologic response of the body to a stimulus is *phasic arousal*. Phasic arousal is abrupt and lasts very briefly, like the surge of adrenalin that is experienced in a sudden and frightening situation. Phasic arousal requires a stimulus. *Tonic arousal* is the body's response over a prolonged period. The body has a norm for tonic arousal, and the brain continually directs the adjustment of hormone levels to keep it at that norm. Stimulation by a strong color causes phasic arousal—an immediate reaction—that can be physiologically measured, but the arousal is short term: *the duration of the effect is not continuous.*

Because exposure to color changes the body's hormonal balance, it can also cause changes in behavior. Colors can be chosen to stimulate, depress, or otherwise alter mood. In environmental design, overstimulation and understimulation have equally negative effects: human beings respond best to living spaces that have color, but not an overload of highly stimulating color. A graphic designer may choose a brilliant color to arouse short-term attention. Restaurant designers use red, in its many variations, to stimulate the appetite. The muted colors of funeral homes are meant to minimize emotional response. An extreme example of color used to modify behavior occurs with a color known as Baker-Miller pink (a bubble-gum pink). It has been hypothesized that exposure to Baker-Miller pink reduces aggressive behavior. The effects begin after a short period of exposure and last about for about half an hour—a perfect demonstration of the body's arousal pattern.

Colors can also be experienced without a stimulus of light. The brain alone, without a light stimulus, allows us to dream in color, or to imagine color with closed eyes. A headache or a blow on the head can trigger vivid images of blue stars. Color can be seen in the mind's eye.

Healing and Color

The eye is not the only organ that responds to light. Light is also absorbed through the skin.

The use of colored light to act on the body through the skin is a routine medical practice. The treatment of jaundiced infants with light is a standard (and effective) therapy, as is the treatment of psoriasis, a skin disease, by exposure to sunlight.

The use of color to heal has a long history. Ancient color therapies included (among other treatments) the application of colored *substances* to the skin. Some were helpful, but not because of their color. They were effective because the applied substance had medicinal properties.

Color therapy remains an active field of study. Most contemporary color therapists ascribe healing properties to different wavelengths, rather than to colored substances. Certain colors of light are thought to have affinities to different parts of the body. The medical establishment is skeptical of these claims, and the practice of medicine by color therapists is illegal in the United States.

Synaesthesia

Synaesthesia is a long-recognized but largely unexplained phenomenon in which one sense responds to the stimulation of another. There are reports of blind persons (and others) who are able to determine the colors of objects through touch. A woman reports a humming sound when she enters a certain red room; the sound stops as soon as she leaves the room. A man reports a strong taste of lemon when he listens to a particular piece of music. Research indicates that the sensory pathways to the brain are connected to each other in ways that can be demonstrated but are not yet understood. The idea that undiscovered connections exist between the senses seems less surprising when we remember what an ordinary thing it is to experience chills—ordinarily a reaction of the skin to change in temperature—from an emotional, musical, or visual experience.

Psychology: Responding to Light

Visual acuity for color, hormonal responses to color, adaptation, lateral inhibition, and synaesthesia are involuntary biologic responses of the body to a stimulus of light. The perception of color also includes involuntary *psychological* responses. The cerebral cortex, the reasoning part of the brain, identifies and organizes a response to each color stimulus that is unconscious, but based on past learning. Stored information has a profound influence on color perception.

One of these responses is a kind of expectation called *memory color*. Memory color means that the viewer makes an unconscious assumption about the color of something, the "orange" of an orange, for example. A viewer influenced by memory color does not report the actual color experience. Instead, what is reported (or even illustrated) is a preconceived idea. A still-ripening Red Delicious apple may be more green than red, but it will be described as red. At times the sea can seem nearly maroon; even then an unthinking — or un*see*ing — artist will paint it as blue.

Memory color affects the perception of objects of familiar coloration. *Color constancy** is a second and equally powerful form of expectation. Color constancy means that the colors of familiar objects retain their identity no matter what the general lighting. The eye and brain together adapt to all general light sources as if they were the same. Colors seen in a daylit room may undergo dramatic changes at night under incandescent lighting, but the viewer is unaware of the differences. An image stored in memory overrides what is actually seen.

A second kind of color constancy occurs when close colors are perceived as being identical. In an all-white kitchen, the white of the refrigerator, the counters, the floor, the cabinets, and the paint may all be different, but the immediate cumulative effect is that they are the same. The various surfaces are categorized mentally as "white," and the concept of "whiteness" prevails over the differences that actually exist.

It is appropriate at times to look for fractional differences between colors (in a design situation, for example), but a constant concern with small color differences would be exhausting if it were applied to daily life. Memory color and color constancy screen out important color differences from ones that do not matter. Because they simplify and edit what is seen, they play a large and proper role in the visual comfort of living with color.

Naming Colors

Color is recognized universally as a particular kind of visual experience. When the brain receives visual information, it identifies it by name. In a widely-accepted study, researchers

* Color constancy is also called chromatic adaptation.

Brent Berlin and Paul Kay determined that ninety-eight languages had names for eleven basic colors. Simpler languages had fewer color names; more complex languages had more names. The languages studied gave names to colors in a consistent order of recognition: first, black and white (or dark and light), then red, followed by yellow and/or green, then blue, brown, orange, purple, and pink.

External evidence tells us that most people see the same thing when they see "red". We accept that something is red not by scientific measurement but by unspoken agreement, common language, and common experience. Green leaves are identified in each language as green, not as orange. Disagreements that arise about the names of colors are about variations within colors, not about broad categories. Something that is called red is simply more red than it is anything else. It may be a bluer red or a yellower red, but no one would ever call it blue or yellow.

Just as no one can know precisely what another person sees, no one can experience anyone else's *idea* about a color. Each individual holds in memory a personal "picture" of the meaning of each color name. Josef Albers observed, "If one says 'Red,' (the name of a color) and there are 50 people listening, it can be expected that there will be 50 reds in their minds. And one can be sure that all of these reds will be very different."[2] In addition, there are hundreds of different reds, and a surprising number of people assume that there is a fixed name for every one. If members of a group are asked to characterize a red object by its color name, the answers are more likely to be "fire-engine red," "cherry red," "spectrum red," or "lipstick red," than simply "red."

Color *study* requires only six names for colors: red, orange, yellow, green, blue, and violet. Each name represents a family of closely related hues. Restricting the names for colors to six words enables the observer to focus on the visual experience. Design and marketing professionals use (and need) romantic names for colors, like Venetian Red, Bermuda Blue, or Aztec Gold because the images that those words evoke play a large role in marketing. Both ways of naming colors are important in design as long as the critical difference between the two is recognized: the six hues of color study deal with eye training, color recognition, and color use; the countless color names of marketing are about product image and sales.

Color as Language: From Name to Meaning

Language is a collection of spoken words that convey ideas and feelings. Each word has the same meaning for those who speak the same language, although single words can have slightly different meanings for different groups of speakers. An American who orders "today's pudding" from a London menu may be surprised to be served a slice of chocolate cake. *Writing* is visible language. It is a visual code for spoken words: a means of preserving words and ideas and a way of controlling the way they are presented.

Dead languages are frozen in time. The meanings of words do not change. Living languages are continually evolving. Words change their meanings over time, or are lost entirely, or are replaced by new ones. Colors, too, can be a language. Colors (or color groups) can be visual codes that communicate ideas and feelings and influence the way ideas are presented. And like words, the meanings of colors can change, or be lost, or be replaced by new meanings over time. *Color is a living language.*

Culture is the social structure that establishes what is important to a group for people. For every individual the meaning of a color, or group of colors, is shaped by a hierarchy of outside forces: culture, spoken language, social status, setting, time, and individual life experience. *Semantics* is the study of the meaning of a word, passage of words, or other form of language—including the language of color. Awareness of cultural differences in the semantics of color is critical to the successful marketing of any product or image destined for the global market. Sometimes a color is only a color, but often it is more.

In *Color, Environment, and Human Response,* Frank H. Mahnke describes the experience of color as a pyramid with six levels of response:[2]

personal relationship
influence of fashions, styles and trends
cultural influences and mannerisms
conscious symbolism-association
collective unconscious
biological reactions to a color stimulus

Each step upward in Mahnke's pyramid represents a narrower interpretation of a color experience. The lowest level is the innate, unlearned response to color that is universal: the physiological response to a stimulus of light and its effects on the midbrain. The cognitive part of the brain becomes a part of the response at the second level, where each sensation is identified by name. "Collective unconscious" responses, like the association of the color red (and also the *word* for red) with blood, are also involuntary and cross-cultural.

At the third level colors become a language that is independent of words. Colors or color groups are used as symbols, or visual codes, for non-color ideas. Symbolic colors have formalized meanings for specific populations. White, the bridal color of the West, is identified as the color of mourning in India. Americans who see "red, white, and blue" interpret it as having an association with the United States, although the French, Chilean, and Yugoslavian flags (among others) employ the same colors.

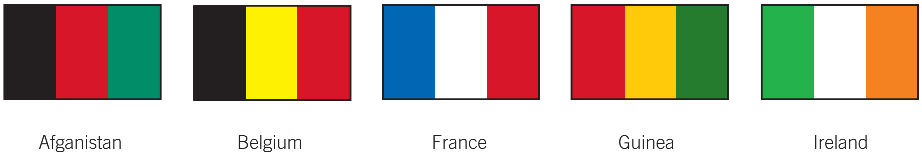


Figure 3-10. *Color Symbolism.* Many national flags share the same configuration. Both configuration and colors are needed to identify each as a national symbol.

Colors or color groups that symbolize major societal concerns like nationhood, death, and marriage tend to maintain their meaning over long periods of time. These color symbols can be thought of as permanent for each population. Black as the color of mourning in the West, or white for mourning in India, for example, are meanings that are unlikely to change. "The East is Red" is both an anthem and a symbol of long-time political reality for Communist China.

Color symbols of lesser social importance tend to be less stable in meaning. Just as words change in meaning, often in politically and socially potent ways, so do the meanings of colors. A color symbol is sensitive to its time as well as to its audience. The Green Party, founded in Europe in the late 1970s, was perceived initially by many as a radical group bent on the destruction of modern society. Alliances of the Green Party with Communist and Socialist groups, known as Red-Green alliances, were viewed as threatening to social stability. In the

Figure 3-11.
Color Symbolism. The color green is recognized immediately as representing concern for the environment. *The Green Promise designation is Benjamin Moore's assurance that its environmentally friendly coatings meet and exceed the strictest industry standards, while also delivering the premium levels of performance you expect from Benjamin Moore.*

twenty-first century, with global warming and the deterioration of the environment everywhere apparent, green has not only lost any negative political meaning in the West, it has become an international rallying color of environmental politics and a powerful tool for advertisers. "Green" products carry the implicit message that using them will help to save the world.

Even with the same audience and within the same time period, however, no color is limited to a single meaning. *Colors are understood as codes for noncolor ideas only when they make sense in context. Colors may inform, but they do not define a situation.* Additional information is needed. The young woman in a long white dress may be a bride—or just a pretty young woman enjoying a summer dress. The green that represents environmental concern in one setting implies youth and inexperience in another. Shakespeare's aging Cleopatra speaks of her "salad days," when she was "green in judgment." New recruits are said to be green. At sea, one turns green from seasickness; in another circumstance, green with envy. Green, the color of Ireland, the "Emerald Isle," is also the color of Islam. And who can tell at a single glance if an orange and black scarf celebrates Halloween—or Princeton?

Figure 3-12.
Safety Colors. School buses and rain slickers are yellow as a reminder to exercise caution.

Some symbolic colors are so important in communicating ideas that their meanings that have been legislated. Color coding plays a central role in conveying safety information for many *vigilance tasks*, which are situations that call for immediate response. The federally mandated OSHA[3] colors used in the United States, and in many cases internationally, communicate physical hazards and safety information. OSHA yellow indicates caution; orange, dangerous machinery or equipment; violet warns of radiation hazard. Red indicates fire-fighting equipment and is recognized world wide as an indicator of danger. Red says "STOP." Green indicates safety, or safety equipment. Safety colors and the situations in which they appear are closely linked in memory. They are processed very rapidly, so that little, if any, additional information is needed. An OSHA yellow rain slicker helps to protect the traffic officer. The same yellow as paint on a chair suggests nothing about safety at all.

When colors are seen with simultaneous and *conflicting* information, the areas of the brain that respond to color compete with other parts of the brain in structuring a response. The resulting delay and confusion in perception, called *Stroop interaction*, takes place because the relative importance of equal and competing streams of information must be sorted out.[4] The word "**BLUE**" written in **RED** will cause a hesitation in the steady flow of reading. An octagonal green traffic sign that said "STOP" would be misperceived—and delay response—with potentially fatal results.

Figure 3-13.
Stroop Interaction.
A delay in comprehension occurs when the different parts of the brain recieve conflicting information at the same time.

"Fashion" colors, the color trends of consumer marketing, are transitory and cyclical. They have a short-term influence on color preferences. Unconscious memory at the individual level, the "personal relationship" to color, is a stronger and more lasting determinant of color responses. When Deborah Sharpe states that "color responses are more tied to man's emotions than to his intellect," the underlying message is that color responses are shaped by experiences and associations that are long-buried in memory. Aunt Agatha made you eat broccoli in her pink kitchen. You have visceral, and very negative, feelings about broccoli *and* pink.

Impressional Color

Impressional or *associative* colors evoke imagery without symbolic meaning. Grayed blue-greens may call to mind the icy cold of a winter sea, or a riot of brilliant greens a tropical forest. Steel gray suggests hi-tech; palest pastels a new baby. These responses can be personal *or* collective, and the slightest shift in hue can alter the imagery. Yellow tilted to orange may suggest warmth and richness, while yellow tilted to green suggests illness. Red is associated with passion of all kinds: "There are reds that are triumphal and there are reds which assassinate,"[4] but thoughts and images raised by a pale rose-red will be quite different from those of deep burgundy.

Color as Words Alone

Written and spoken *words* for colors communicate the same symbolic ideas as actual colors, but they are understood more indirectly. Words are processed as thought rather than as sensory experience. The *immediacy* of a color symbol diminishes when it is presented as words. Its *meaning* is unchanged. Reading the words "red, white, and blue" takes longer to process than the sight of a flag in full color. Color meanings of all kinds are inextricable from descriptive writing. A colorful personality is understood to be vital and interesting; a gray individual, not at all. No one has written more comprehensively, or with more eloquence and scholarship, on the imagery and symbolism of colors than Paul Theroux:

> Fox-red *tenné* in the language of chivalry shows a somewhat burnt tone. And garnet red with its low brilliance and medium saturation is a sort of "pigeon blood" or "Spanish wine." Cranberry red has a saucy sharpness to it, with a hint of yellow. Bluish red, popular in lipsticks, cardigans, and the aura of dramatic personalities....[5]

Does anyone doubt that celebrities have a bluish red aura? Theroux says it all.

Endnotes

1 Rodemann 1999, page 155.
2 Mahnke 1982, page 11.
3 OSHA United States Congress Occupational Safety and Health Act of 1971.
4 Varley 1980, page 132, quoting Leon Bakst.

Chapter 3 Highlights

- The experience of color begins with a sensation, a response to a stimulus of light. Both stimuli and sensation are measurable. A sensation is followed by perception; the understanding of what has been sensed. A perception can only be described. Most perceptions occur unconsciously and at such high speed that they seem simultaneous with sensation.

- Visual acuity for color is the ability to detect differences between wavelengths (colors) of light. The threshold of color vision is the point at which a difference between two similar hues can no longer be discriminated. An interval is a step of change between visual sensations. An individual's threshold establishes the single interval: the point at which a detectable middle step can no longer be inserted between two close colors.

- Parent-descendant color mixtures are illustrated as three colors in a linear series, with a "parent" at each end and a middle interval between them. Even intervals occur when the middle step is visually equidistant between the two parents. In a series of even intervals, each step is the midpoint between the samples on either side of it. Images composed of even intervals are more quickly and easily understood than those in which intervals are uneven or random. A gradient is a series of progressive, even intervals so close that individual steps cannot be distinguished.

- The eye is a sense organ that detects light. Light enters the eye through the pupil and falls on the retina, which is made up of light-sensitive receptor cells called rods and cones. These connect to the optic nerve, which transmits the message to the brain. Rods and cones respond selectively to available light. Cones dominate vision when a great deal of light is present. Cones are responsible for color vision and for the ability to see detail. The fovea is a tiny area at the back of the eye that contains only cones. It detects patterns of light and dark and color with the greatest clarity.

- The sensation of light is received in two areas of the brain. The cerebral cortex recognizes, interprets, and structures a response to each stimulus. The midbrain contains the center for regulation of blood pressure, body temperature, and glands that produce hormones. Sensations of light transmitted to the midbrain act as a biological stimulus to the central nervous system. Changing the strength of a color stimulus can cause a change in the body.

- Adaptation is an involuntary response of the eye to the quantity of available light. The retina moves back and forth between rod and cone dominance as available light increases or decreases. Lateral inhibition increases the eye's ability to distinguish edges in patterns of light and dark. The greater the quantity of light, the more lateral inhibition takes place.

- The immediate response of the body to a stimulus is phasic arousal, which is abrupt and brief. Stimulation by color causes phasic arousal but the duration of the effect is not continuous. Tonic arousal is the body's response over a prolonged period. The human body is genetically adapted to function at a normal level in response to the sun's pattern of energy emission. It has a norm for tonic arousal and continually adjusts hormone levels to keep it at that norm. Exposure to color changes the body's hormonal balance and can cause changes in behavior.

- Colors can be experienced without a stimulus of light. The brain allows dreaming in color and imagining color with closed eyes. A headache or a blow on the head can trigger a color response. Light is also absorbed through the skin. The use of colored light to act on the body through the skin is a routine medical practice. Synaesthesia is a largely unexplained phenomenon in which one sense responds to the stimulation of another.

- Memory color is a psychological response to a stimulus of color. The viewer makes an unconscious assumption about the color of something and reports a preconceived idea rather than the actual color experience. Color constancy means that the colors of familiar objects retain their identity no matter what the general lighting. A second kind of color constancy occurs when close colors are perceived as being identical.

- Colors and color groups are used as symbols. Symbols for major societal concerns like nationhood tend to maintain their meaning over time and can be thought of as permanent for each population. Lesser symbolic meanings can change, be lost, or be replaced over time. Semantics is the study of the meaning of a words, passages of words, or other forms of language. Awareness of cultural differences in the semantics of color is critical to the marketing of any product intended for the global market. Words for colors communicate the same symbolic ideas as colors, but less quickly. Words are processed as thought rather than as sensory experience.

- Color coding plays a central role in conveying safety information. Stroop interaction takes place when colors are seen at the same time as simultaneous and conflicting information. Areas of the brain that respond to color meaning compete with other parts of the brain in structuring a response.

4

THE VOCABULARY OF COLOR

Hue / The Artists' Spectrum / Primary, Secondary, and Intermediate Colors / Saturated Color / Other Spectrums, Other Primaries / Chromatic Scales / Cool and Warm Colors / Analogous Colors / Complementary Colors / Tertiary Colors: Chromatic Neutrals / Black, White, Gray / Value / Value and Image / Transposing Image/ Pure Hues and Value / Tints and Shades / Monochromatic Value Scales / Comparing Value in Different Hues / Saturation / Saturation: Diluting Pure Hues with Gray / Saturation: Diluting Pure Hues with the Complement / Tone

"When I use a word," Humpty Dumpty said, in a rather scornful tone," it means just what I choose it to mean—neither more nor less."

—Lewis Carroll

The words for colors in everyday life—red, green, blue, and so on—do not have precise meanings. Instead, each word is a code for a range of similar sensations. The same is true for words that describe colors, like brilliant, dull, dark, or light. Red is red, and never blue, and brilliant is never dull, but at the same time, these words in conversation can represent a number of different visual experiences.

When a word is used to identify a color sample, or as the verbal expression of a color not seen, it means something slightly different to each person. Mary and John see the same red-orange sample and respond to it in personal ways. Mary calls it red; John insists it is red-orange. Not everyone senses colors in exactly the same way, and even if they did, individuals do not *think* of colors in exactly the same way. The result is a stalemate; a difference of opinion; an inability to agree on what a particular sample *is*—and difficulty in communicating ideas about it. It makes no difference whether a color is seen as pure light, or as a solid object, or as a printed page. Each person interprets and names colors in his or her own way. Color is a *subjective* experience. One man's peach is always another man's melon.

The design process calls for a vocabulary that communicates color ideas with more precision, but no new words are needed for this. If a color cannot be precisely *identified* by words, it can nevertheless be described. Colors have basic attributes that can be observed and named. Whether these are called qualities, aspects, dimensions, or something else, they all refer to the same thing: qualities that are present in colors of all kinds; colors of light or colors of ink, colors that are glossy or matte, transparent or opaque, chalky or clear. An observer with a trained eye can use these attributes to describe a color relative to another, similar one, and to communicate differences between them with reasonable precision. Color corrections can be directed in the same way.

The vocabulary of working with color also includes words that describe interrelationships between colors. Together, the terms of description and interrelationship make it possible to convey ideas about color using words whose meanings are clear, consistent, and objective.

Three qualities of color are already familiar:

> *Hue*: the name of the color: red, orange, yellow, green, blue, or violet
>
> *Value*: the relative lightness or darkness of a color
>
> *Saturation* or *chroma*: the hue-intensity or brilliance of a sample,
> its dullness or vividness

Each word communicates an independent idea, but the ideas are independent only for the purposes of study. These attributes are present in every color, and all are needed to describe it. A color sample may have additional characteristics, like opacity or translucency, but it can always be described first in terms of its hue, value, and saturation.

Hue

Hue means the *name* of the color. In science, the colors of light, or *spectral colors*, can be established precisely by a measurement of wavelength, and the words "hue" and "color" are interchangeable. In everyday speech (including in this book), the word "color" is used in two different ways. It can mean (more precisely) the hue of something or (more generally) the complete visual experience of its hue, value, and saturation together. Only the context in which it is used tells which meaning is intended. "Hue," however, means *only* the name of the color.

Chroma is a synonym for hue. It is part of some familiar color words:

Chromatic: Having hue
Achromatic: Without hue
Polychromatic: Having many hues
Monochromatic: Having one hue only

It has been theorized that the average person can distinguish about 150 colors (hues) of light, and every one can be described using one or two of only six words. The only names ever needed to describe hue are:

RED ORANGE YELLOW GREEN BLUE VIOLET

A color is called by the name of its most obvious, or dominant, hue. Every color name represents a family of related hues. Nearly all color samples include more than one hue, but *one hue is most apparent* and others are present in smaller proportion. A sample may seem to be pure yellow until it is placed next to a different yellow sample. Suddenly, one yellow is seen to contain a bit of green, the other a fraction of orange. Both are *called* yellow because yellow predominates in each. Using the word "*contains*" helps to evaluate colors. "This yellow contains some orange" is perfectly descriptive. It identifies the principal hue and a second one that modifies it.

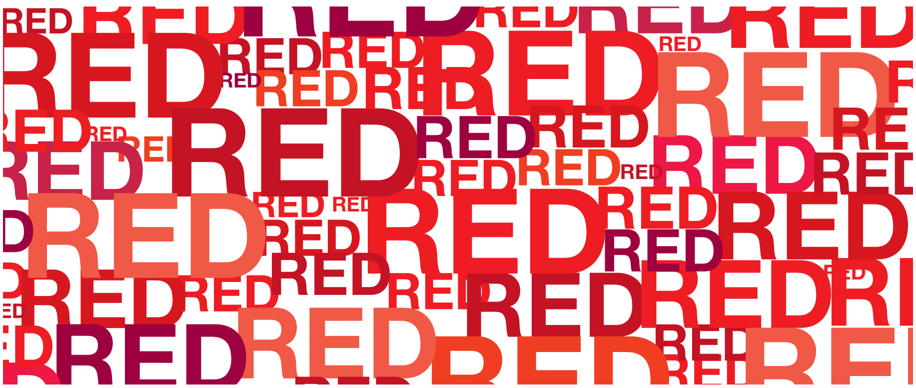
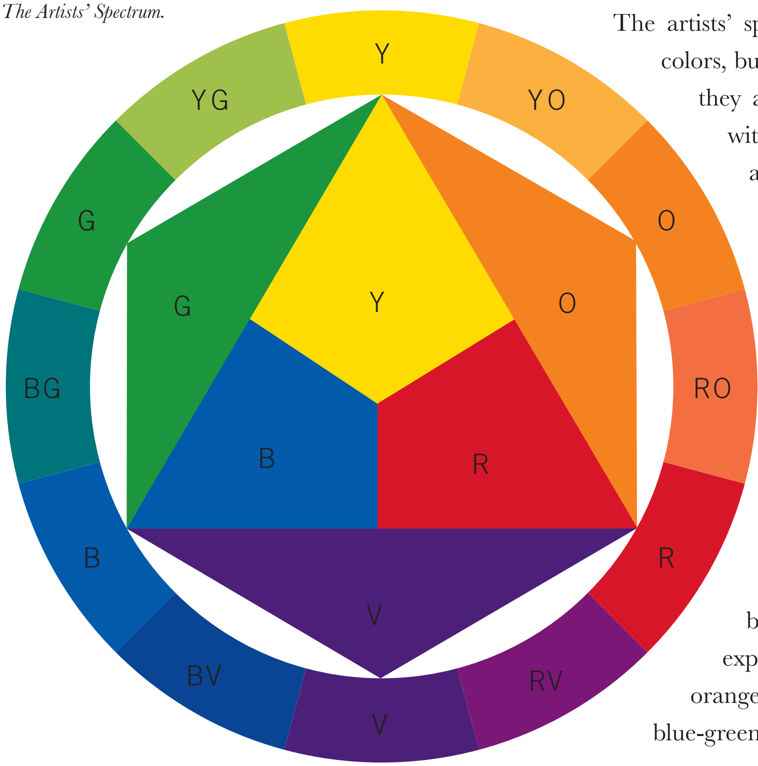


Figure 4-1. *Color Names.* Color names are not absolute. Every color belongs to a enormous family of related hues.

The Artists' Spectrum

The *artists' spectrum* is a circle that illustrates hues in their natural (spectral) order. The spectrum of visible light (additive color) is linear, moving from short wavelengths of light (violet) to long ones (red), and the order of its colors is fixed. The artists' spectrum is also fixed in its order of colors, but it has six hues instead of seven, and they are presented as a continuous circle, with violet forming a bridge between red and blue. The artists' spectrum is also called the *color circle* or *color wheel*.

Figure 4-2.
The Artists' Spectrum.



There are too many hues in the range of human vision to include all of them in one circle, so the artists'spectrum is a sort of visual outline, or synopsis, of all visible hues. The basic spectrum is made up of six hues: red, orange, yellow, green, blue, and violet. An expanded spectrum has twelve hues, but *no new color names are introduced*. The expanded spectrum includes yellow-orange, red-orange, red-violet, blue-violet, blue-green, and yellow-green.

The artists' spectrum is limited to six or twelve hues only because this is a concise, easily illustrated figure. It can be expanded to any number of hues as long as the added colors are inserted at regular intervals in all hue ranges. There can be six, twelve, twenty-four, forty-eight, ninety-six, or more hues (but not thirty-seven or fifty-one). The only limits to the number of places on a color circle are the limits of human visual acuity and the practical problems of illustrating it.

Color circles can be illustrated in any medium. If the medium is a display of light on a screen, the colors will be sharp and clear; perhaps even measurable as true spectral hues. A subtractive medium like gouache or acrylic paint illustrates colors in a less measurable way. As long as the hues are in sequence and the intervals well-spaced, color circles can vary a good deal in appearance and be equally correct as representations of the visible hues.

Primary, Secondary, and Intermediate Colors

Red, yellow, and blue are the *primary colors* of the artists' spectrum. They are the simplest hues. They cannot be broken down visually into other colors or reduced into component parts. The primary colors are the most different from each other because they have no elements in common. All colors on the artists' spectrum are mixed *visually* from the primaries red, yellow, and blue. Green, orange, and violet are the *secondary colors* of the artists' spectrum. Each secondary color is an even interval, or visual midpoint, between two primary colors:

Green is the middle mix of blue and yellow.
Orange is the middle mix of red and yellow.
Violet is the middle mix of blue and red.

The secondary colors are less contrasting in hue than the primary colors. Each secondary color has one primary in common with each of the others. Orange and violet each contain red, orange and green each contain yellow, and green and violet each contain blue.

Yellow-orange, red-orange, red-violet, blue-violet, blue-green, and yellow-green are *intermediate colors.* They are the midpoints between the primary and secondary hues. Many times these colors are referred to, incorrectly, as tertiary colors.

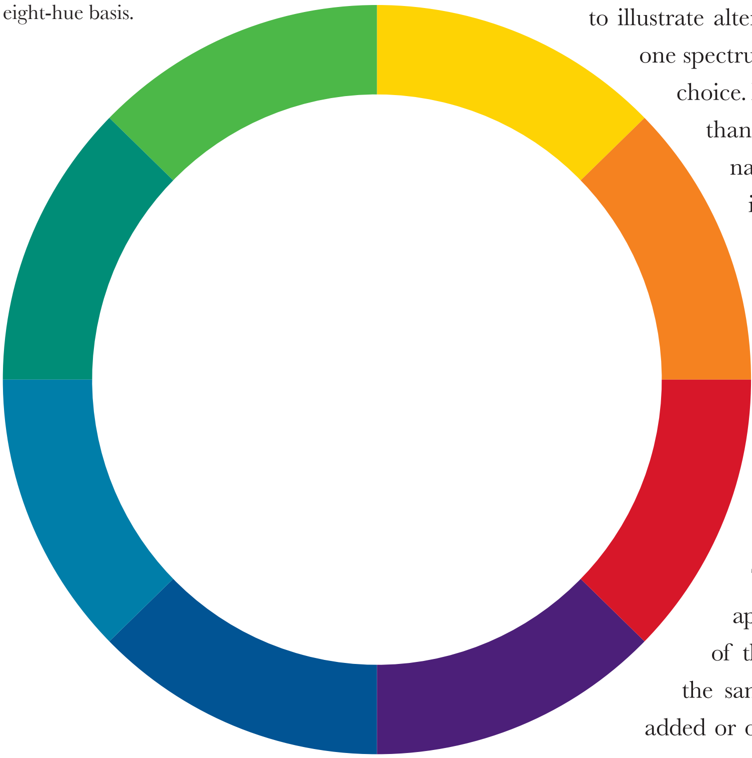
Saturated Color

A *saturated color* is a hue in its strongest possible manifestation. The reddest red imaginable, or the bluest blue, are saturated colors. Saturated colors are also called *pure colors* or *full* colors. They are at *maximum chroma.* Saturated or pure colors can also be defined by what they do *not* contain. A saturated hue is made up of a single primary color or two primaries in some mix or proportion, but never includes a third primary. A saturated hue does not contain black, white, or gray.

Saturated colors are not limited to the six or twelve "named" hues of the artists' spectrum. *As long as a color contains only one or two primaries and is undiluted by black, white, or grey, it is a saturated color.* Imagine the full range of visible hues as a circle with each color blending into the next, like a circular rainbow. Any hue, at any point on that circle, is a saturated color. The only limit to the number of saturated colors is the limit of human color vision.

Other Spectrums, Other Primaries

Figure 4-3.
Alternative Spectrums. Wilhelm Ostwald's spectrum has an eight-hue basis.



The artists' spectrum illustrates one color-order system. It is familiar, visually logical, easy to represent as a two-dimensional figure, and allows for theoretically unlimited expansion. Scientific and nonscientific disciplines use other spectrums to illustrate alternative color-order systems. Choosing one spectrum instead of another is exactly that: a choice. No spectrum is inherently more correct than another. The circles may vary in the names of colors, the number of colors illustrated and in the assignment of what might be called "prime points" on the wheel. Wilhelm Ostwald, for example, predicated an eight-hue spectrum that includes sea-green (blue-green) and leaf-green (yellow-green). Psychologists construct a four-hue spectrum with red, green, yellow, and blue as the primaries.

The different color circles may at first appear to conflict, but they are all variants of the same color-order idea. All recognize the same sequence of colors. Hues may be added or omitted. There may be a slight shift in the placement of opposites. Munsell, for example, places blue-green, not green, opposite red. But no spectrum places red next to green, or orange next to blue. Arguments made for the number of colors included and their names are intellectual exercises. All color circles include the primary hues in some way, and all follow the same color order.

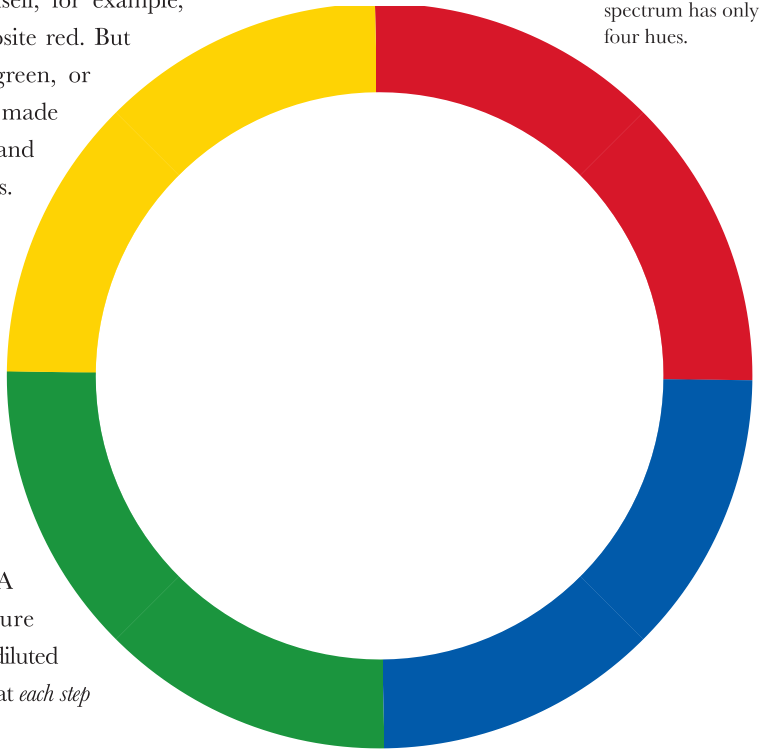


Figure 4-4.
Alternative Spectrums. The psychologist's spectrum has only four hues.

Chromatic Scales

A *chromatic scale* is any linear series of hues in spectrum order. A series of hues between blue and orange (blue-green-yellow-orange), for example, is a chromatic scale. A chromatic scale can illustrate pure (saturated) colors or more complex, diluted colors. Its defining characteristic is that *each step in the progression is a change in hue*.

Cool and Warm Colors

Cool and *warm* are words used to describe two opposing qualities of hue. Cool colors contain blue or green: blues, greens, violets, and steps between them. Warm colors are reds, oranges, yellows, and steps between them. Warmth or coolness in hues is sometimes referred to as color temperature.

The primary colors are weighted toward the warm. Only blue is cool, while both red and yellow are considered warm. As a result, the entire spectrum is more heavily "warm" than it is "cool." Blue is the polar extreme of cool, and orange, made of red and yellow, is the polar extreme of warm.

Warmth and coolness in colors are not absolute qualities. Any color, even a primary, can appear warmer or cooler relative to another color. There are cooler reds (closer to violet) and warmer ones (closer to orange). Violet and green are generally considered to be cool colors, but it is possible to describe one violet as warmer than another violet because it contains more red.

The terms "cool" and "warm" are helpful for describing families of colors or for comparing colors for warmth or coolness alone. They are less useful terms when hues need to be adjusted. Directing a color change toward a specific hue communicates more clearly. "This violet is too warm. Cool it off, add some blue. This red is too cold. Warm it up; bring it closer to orange."

Analogous Colors

Analogous colors are hues that are adjacent on the artists' spectrum. *Analogous color groupings contain two primary colors but never the third*. Analogous colors are among the most frequently used in design. Analogy affords the designer an opportunity to add colors to a design without changing the balance of an already established palette. A composition of red and orange is enriched, not changed, by the addition of red-orange.

Figure 4-5.
Analogous Hues. Analogous hues contain two primaries, but never the third.

The traditional definition of analogous colors is “a group of colors consisting of a primary color, a secondary color, and any and all hues that lie between the two.” In this time-honored definition, a primary hue dominates the grouping. Every color by this definition contains (visually) *at least* 50% of the same primary. Typical groups of this kind are blue, blue-violet, and violet (blue dominant); yellow, yellow-green, and green (yellow dominant); and red, red-orange, and orange (red dominant).

A more generous definition describes analogous colors as *a group of colors that are adjacent on the color wheel and lie between a primary and secondary color.* This broader definition includes color groups in which a primary or secondary color does not actually appear. Green, yellow-green, and yellow-yellow green are analogous, but no primary is present; red, red-red-violet, and red-violet are analogous but no secondary is present. As long as a group of hues is bounded by a primary and secondary color, and does not extend beyond either, the colors are analogous.

No matter how many hues are included within a primary-to-secondary range, the most successful analogous groupings are made up of even intervals of hue. This does not mean that the *placement* of colors in a composition must be in linear order. It means only that the overall composition has the best chance of success when the steps between colors are evenly spaced.

Analogy is not confined to pure colors. Colors that have been diluted in any way can also be analogous. *Analogy is a relationship between hues no matter what their value or saturation.*

Complementary Colors

Complementary colors are hues that are opposite one another on the artists' spectrum. Together, the two are called *complements* or a *complementary pair*. The basic complementary pairs of the artists' spectrum are:

Red and green
Yellow and violet
Blue and orange

In each of these pairs, one half is a primary color and the other half is the secondary that is a mixture of the remaining two primaries. *The three basic complementary pairs are different from each other in the exactly the same way as the primary colors. Neither half contains a hue in common with its opposite.*

The complementary relationship is not limited to the three basic pairs. Whether a spectrum is illustrated with six hues or ninety-six, a straight line drawn across the center of the circle from any point connects a pair of complementary colors. *Every complementary pair includes the three primary colors in some mix or proportion.* These additional complementary pairs are less contrasting than the basic pairs because each color contains one primary in common with its opposite. The complementaries blue-green and red-orange, for example, each contain yellow. Yellow-green and red-violet each contain blue, and blue-violet and yellow-orange each contain red.

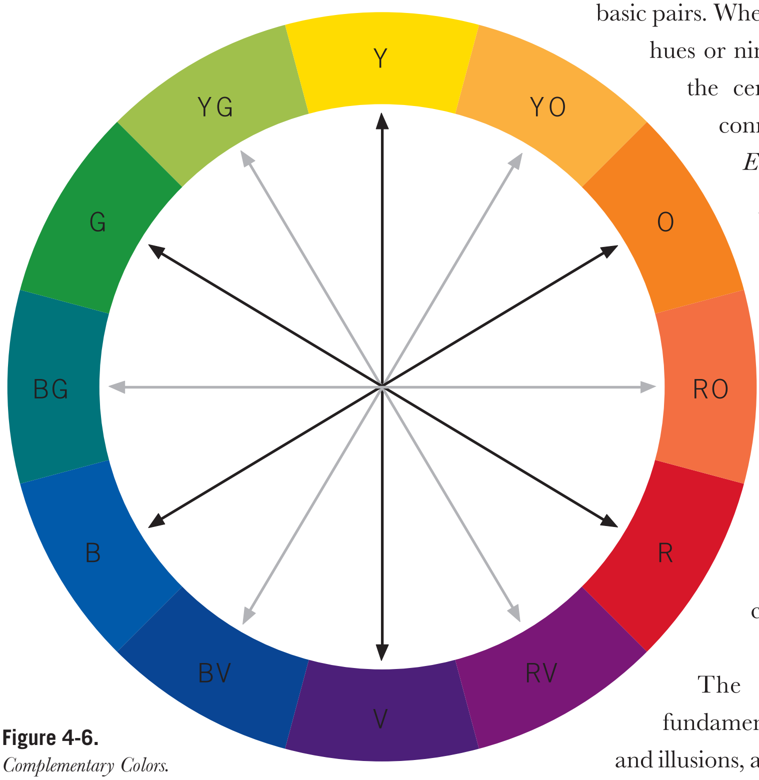


Figure 4-6.
Complementary Colors. Complements are opposite each other at any point on the artists' spectrum.

The complementary relationship is fundamental to color vision, to special effects and illusions, and to color harmony. Every color has an opposite that is its complement. The complementary relationship exists whether colors are pure hues or have been diluted in some way. *No matter what the value or saturation of a color, it maintains at all times a complementary relationship with its opposite.*

Tertiary Colors: Chromatic Neutrals

When a pair of complements is mixed together in a subtractive medium, the middle mix absorbs (imperfectly, within the limits of the medium) all of the wavelengths of light, so that little or no hue reflects back to the eye. This effect can also be simulated on screen. Another way to characterize complements is to say that they are a pair of colors that, when mixed, produce a sample of no discernable hue. These are the *tertiary colors*.

Tertiary colors are an enormous, almost limitless class of colors. Tertiary means "of the third rank."[1] Tertiary colors are defined as "gray or brown, a mixture of two secondaries," which can be said more simply as "gray or brown, a mixture of three primaries." Tertiary colors are a sort of color soup, containing all possible hue ingredients but with no single hue apparent in the mixture (although it is almost always possible for a trained eye to identify the ingredients).

A color that has been dulled slightly by the addition of its complement is a muted hue, not a tertiary color. Red dulled by the addition of a little green is still red. Tertiary colors are sometimes called achromatic neutrals, but it is more accurate to describe them as *chromatic* neutrals. They cannot be identified as hues, but neither are they a mix of black and white.

The word *brown* is used to describe many of the colors in this family. Brown is not a hue. We say "brown" instead of "tertiary color" because it is common usage and describes a family of familiar sensations. Brown typically has an orange or red overtone, rather than a cool one. Colors are not more or less brown, but browns can be more or less red, or orange, or yellow, or even more blue, green, or violet.

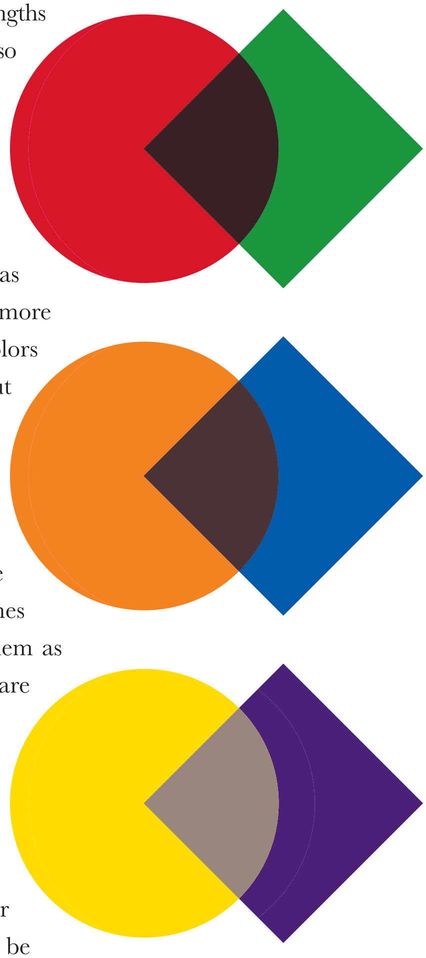


Figure 4-7.
Mixing Complements. When complementary colors are mixed to their midpoint, the result is a sample of no discernible hue.

Black, White, Gray

Black and white are *achromatic*. They are without hue. Absolute whites and blacks exist only in the medium of light. Light can be measurably white, and a total absence of light can be completely black. Subtractive media for black and white are not perfectly achromatic. Even the best quality colorants contain some suggestion of hue.

True grays, or mixtures of black and white, are also achromatic. Subtractive colorants for gray also contain a suggestion of hue. Grays are generally categorized as warm or cool, rather than as "orange" or "pink" grays, or "blue" or "green" ones. When warm and cool grays are placed next to each other, the presence of hue in each becomes immediately apparent. Even when a gray seems truly achromatic, placing it next to an area of color will cause it to lose its apparent neutrality and take on a suggestion of warmth or coolness.

Value

Value refers to relative light and dark in a sample. Hue is circular and continuous, but value is linear and progressive. A series of steps of value has a beginning and an end. *Value contrast exists whether or not hue is present.*

Value is first and most easily understood as a series of steps from black to white. White is the highest possible value. Middle gray, the midpoint between black and white, is a middle or medium value, neither dark nor light. Black is the lowest possible value. A *value scale* is a series of ever-doubling steps that move between the poles of dark and light. Each step in a value series is a middle interval between the two on either side of it: half as dark as the one before it, and twice as dark as the one following.

Figure 4-8. *Value Scale.* A value scale moves from dark to light.

Value and Image

Only value contrast makes objects distinguishable from their background. Hue and saturation are not factors in the perception of image. The ability to discriminate objects from their background, or figure-ground separation, depends only on dark-light contrast. Black-and-white drawings, printed pages, and film images are completely understandable. People with a deficit in color vision are functional in a seeing world because "color-blind" really means "hue-blind."

The degree of contrast between light and dark areas determines the strength, or graphic quality, of an image. Black and white, the polar extremes of value contrast, create the strongest images. Differences between form and their background may be further emphasized by contrasts of hue or saturation, but difference in value is the only factor in the ability to see a distinct edge between colors.

High-contrast images are not always desirable. Strong contrasts of dark and light induce lateral inhibition, and that means that the eye is working. Viewing extremely high-contrast images over a sustained period can cause eye fatigue. Superhighway signs in dark green and white, rather than black and white, provide good contrast at a slightly reduced level, decreasing the risk of eye fatigue—and accidents.

The closer in value an image is to its background, the harder it is to see. A light green frog on a light green leaf is invisible to predators, but resting on a dark green leaf, the frog is easy pickings. When there is no value contrast at all—like an igloo in a snowstorm—there is no image at all.

Figure 4-9. *Value and Image: Graphic Quality.* The strongest images contrast sharply in value with their background. Images are less distinct when the two are similar in value.

Line is an elongated area of color that has value contrast against its ground. There are thick lines and thinner ones, broken lines and lines of varying width, but all lines have the same two attributes: great length in relation to little width, and value contrast against the ground. Line has tremendous visual power. When blocks of color are similar in value they are difficult to make out, but the thinnest contrasting line between them creates an immediate separation.

Transposing Image

Value contrast makes objects distinguishable from their background. The placement of different values relative to one another *within* an image give it individual identity.

In order to transpose an image from one color to another, the number and placement of values within the two images must be identical. If there are five values present in the first image, there must be five in the second, and the placements of light, medium, and dark areas must be the same in both. Scrambling the placement of values within an image creates a new, different one.

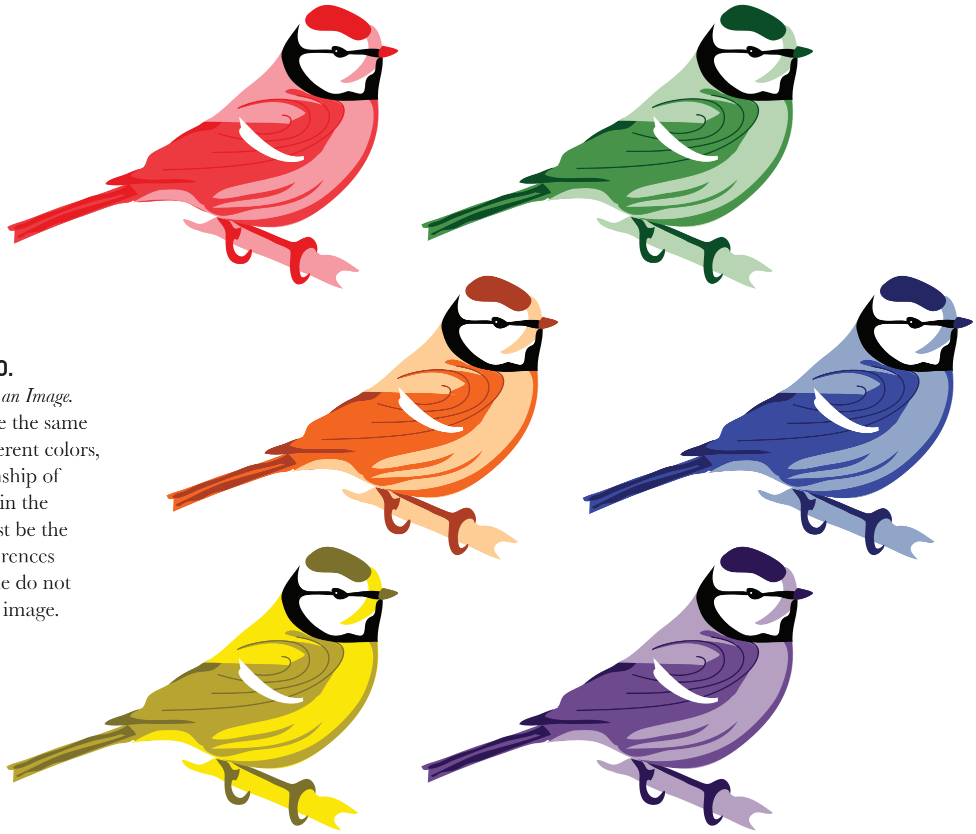


Figure 4-10. *Maintaining an Image.* To illustrate the same bird in different colors, the relationship of values within the images must be the same. Differences in hue alone do not change the image.

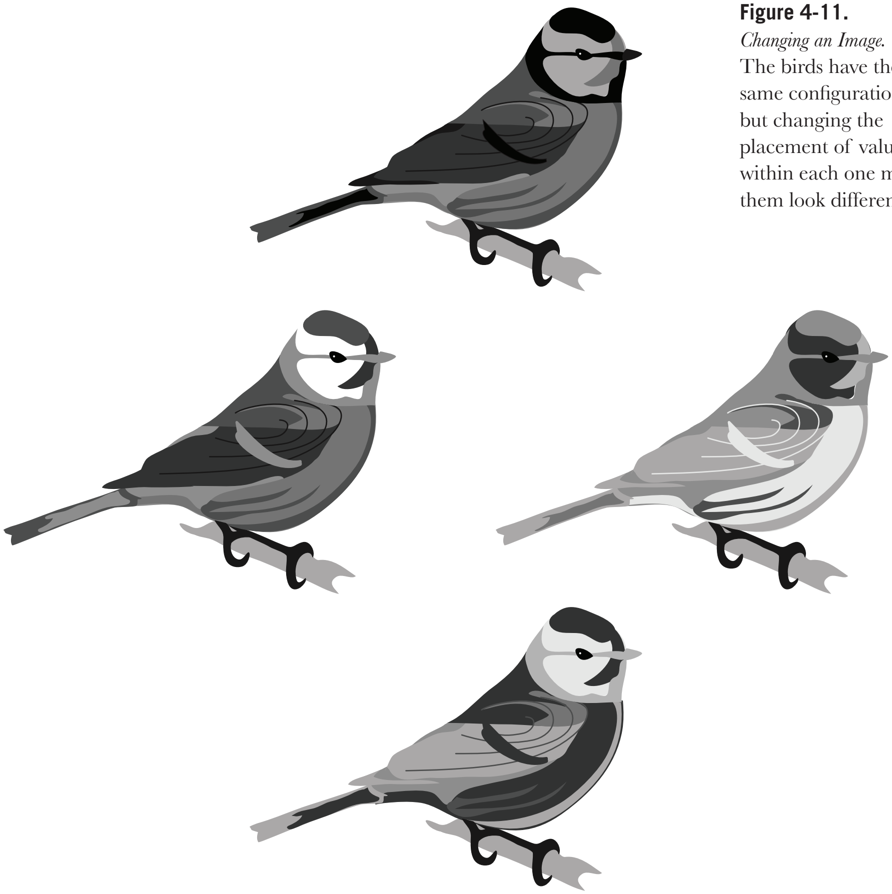


Figure 4-11.
Changing an Image.
The birds have the same configuration, but changing the placement of values within each one makes them look different.

Pure Hues and Value

Value is also associated with the idea of *luminosity*. A hue that is luminous reflects a great deal of light, appears light, and is high in value. A nonluminous hue absorbs light, is dark, and is low in value. It is immediately apparent that each of the six spectrum hues is at a different level of value. Yellow is lightest by far, and violet the darkest.

It is also apparent that red, orange, green, and blue are darker than yellow and lighter than violet. What is less apparent—but important to understand—is that *the saturated colors are* *not at evenly spaced steps of value*. The value difference between yellow and green, for example, is much greater than the difference between blue and green. Blue and green are closer in value. The artists' spectrum illustrates colors at evenly spaced intervals of *hue*, but *not* at evenly spaced intervals of value.

An argument is sometimes made for expanding the spectrum with more intervals in the yellow-to-blue and yellow-to-red ranges than in the blue-to-red. Yellow is much lighter than blue, and the great difference in their values makes it possible to set up many perceptible steps between them. The same is true for yellow and red. Blue and red are closer in value, and the number of perceptible steps that can be established between them is fewer.

A spectrum illustrated in this way has many more steps in the yellow, orange, and green ranges than in the red, violet and blue. This creates an immediate problem in establishing complementary pairs. So many possible intervals can be illustrated between colors that contain yellow that they might actually end up opposite each other on a circle.

The purpose of the spectrum is to illustrate the full range of visible hues. No matter how many intervals are inserted between yellow-to-red and yellow-to-blue, *no new hue is introduced*. To say that there are more hues between yellow-to-red and yellow-to-blue than between red-to-blue misunderstands the nature and purpose of the spectrum.

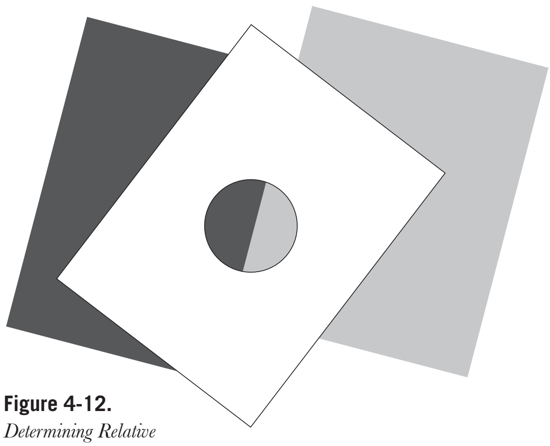


Figure 4-12. *Determining Relative Value.* A white frame that isolates samples is helpful in making value comparisons. Any opaque white paper with a small hole cut in it works well.

Tints and Shades

Only occasionally are colors used at full saturation. In most situations, hues are diluted in one or more ways. The simplest way to dilute pure colors is to change their value by making them lighter or darker. A *tint* is a hue that has been made lighter. A *shade* is a hue has been made darker.

Tints are sometimes called hues with white added; shades are sometimes called hues with black added. "Added black" or "added white" is not meant as a recipe for paint mixing.

"Added white" is another way of saying "made lighter," and "added black" is another way of saying "made darker."

Tinting makes a hue more light-reflecting. A great deal of added white creates tints that are just barely identifiable as their original hues. A small amount of white results in a strong tint that is brilliant and light-reflecting, often creating a more intense color experience than that of the original saturated hues. Violet, the darkest of the pure hues, seems more chromatic when white is added. The same can sometimes be true of blue, green, or red. Strong tints are sometimes mistaken for saturated colors, but *no matter how hue-intense and brilliant a tint may be, it is a diluted hue, not a saturated color.*

Shades are reduced-hue experiences. Black absorbs all wavelengths of light, so adding black reduces light reflectance. Even slightly shaded hues are rarely mistaken for saturated colors. The range of shades is less familiar than tints, but it is just as extensive. Hue can be detected in a sample that appears at first to be completely black by placing it next to another, different black. Any hue that is present in either sample becomes instantly apparent.

Monochromatic Value Scales

A *monochromatic value scale* is a single hue illustrated as a full range of values in even steps, including both tints and shades. Monochromatic value scales are slightly more difficult to illustrate than black-gray-white scales. No one seems to have difficulty imagining (or illustrating) tints of pure colors. The dilution of any color with white makes it more light-reflecting and more visible. Understanding and illustrating shades can be more difficult. Shades of cool colors, like dark blue or dark green, are reasonably easy to

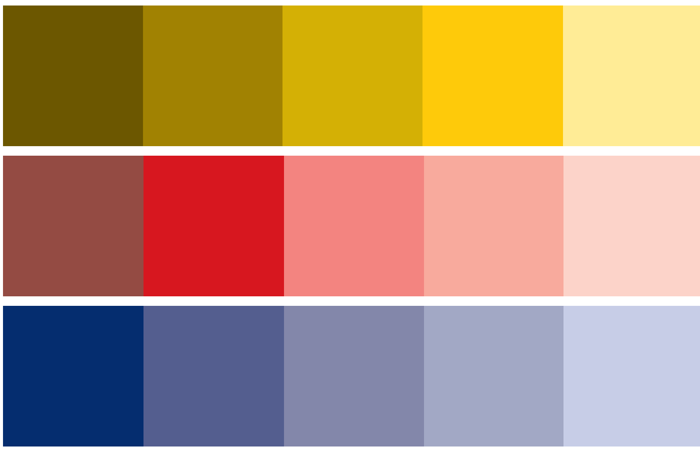


Figure 4-13. *Hue and Value.* Any hue can be illustrated as a full range of tints and shades, from near-white to near-black.

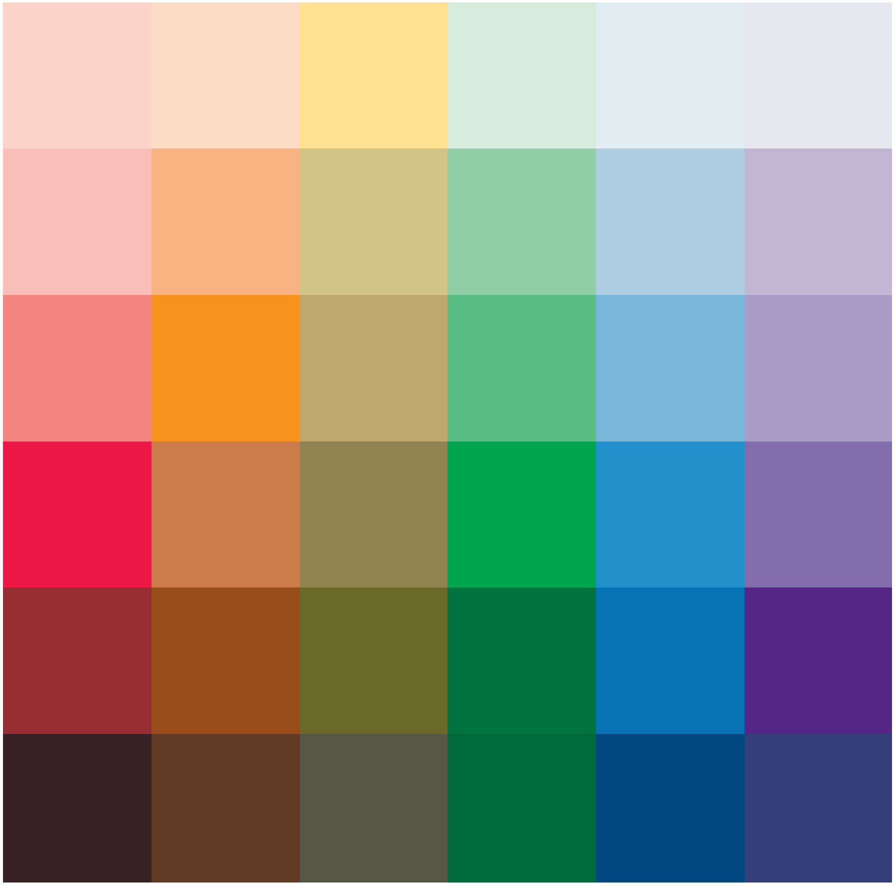


Figure 4-14. *Saturated Hues and Value.* A chart of seven steps of equal value in different hues illustrates how a single step of value may contain both tints and shades. On a limited chart such as this one, some saturated hues may not appear at all. *The accuracy of this image is limited by the constraints of CMYK printing.*

identify, but shades of warm colors can be problematic. Saturated yellow is so high in value that many people find it particularly difficult to associate yellows (and oranges) with their shades. It is hard to imagine the combination of yellow or orange with black because the essential nature of yellow, alone or as a component of orange, is so luminous and opposite to dark. But like all colors, yellow and orange can be illustrated as a full range of values, from near-white to near-black.

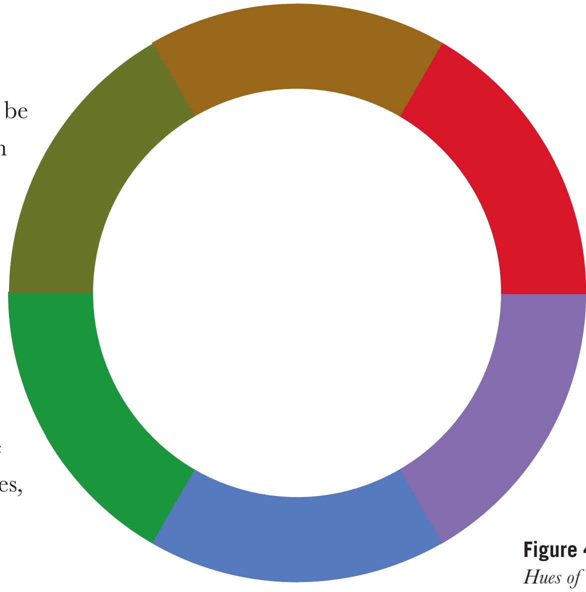


Figure 4-15. *Hues of Equal Value.* A spectrum of hues of equal value requires that some hues be saturated, some tints, and others shades. Is this yellow a pure hue, a tint, or a shade? What is the value of the violet?

Comparing Value in Different Hues

Deciding which of two gray samples is lighter or darker is not very difficult. Deciding which of two samples of a single hue is lighter or darker is also straightforward. Determining which of two *different* hues is lighter or darker than the other is difficult. It is more difficult when one hue is warm and the other is cool, and most difficult when the hues are complementary. Only saturated red and green are close to equal in value. In order for other complementary colors to be made equal in value to each other, one must be made darker or lighter. Adding a great deal of black to yellow can make it as dark as violet. Adding a great deal of white to violet can make it as light as yellow.

Hue is not a factor in "readability." Only value contrast creates an image. When two or more hues are used together, it is the value contrast between them, not the hue contrast, that determines the strength or weakness of the resulting image.

Figure 4-16. *Hue, Value, and Graphic Quality.* Contrast of dark and light, not hue, determines the strength of an image.

Saturation

The third descriptive quality of color is *saturation*, or *chroma*. Saturation and chroma refer to *hue intensity,* or the amount of pure color in a sample. A saturat<u>*ed*</u> color is a color at its fullest expression of hue. It is a color at *maximum chroma*. Saturat<u>*ion*</u> is a comparative term. It describes the contrast between dull and vivid. Saturation, like value, is linear and progressive. The beginning of a saturation scale is a color that is hue-intense. The end step is a color so muted that its hue can just be identified.

Saturation is a color quality that is distinct from value. Shades are already reduced in saturation because they contain black, so it is instinctive to think of muted colors as dark. But any hue or tint can be reduced in its chroma—made less vivid—*without* changing its value. A tint of red-orange can be muted to the color of light clay. The two contain the same hue and are equal in value, but one is a brilliant color and the other is muted.

Brilliant colors have a high level of saturation. A brilliant color may or may not *also* be a saturated color. Hues that contain a high proportion of yellow (yellow, yellow-orange, orange, and yellow-green) are good candidates for both brilliance and high saturation. Brilliant colors that do not contain yellow, or have a lower proportion of yellow, are more likely to be tints. Red-violet diluted with a little white is a brilliant color: a tint with a high level of saturation.

Muted (dull) colors are at a low level of saturation. Any color can be muted in steps from full saturation to very dull. As long as a color sample can be identified by its hue, it *is* a hue; just one that is muted. Dull orange is still orange. When a sample is so muted that its hue is no longer apparent, it has become a tertiary color: a sample that is chromatic but has no identifiable hue. Colors that lie at the threshold between muted hues and tertiary colors provide a classic situation for arguments set off by the way different individuals see and think about colors. Jane's idea of "burnt orange" may be John's idea of "brown."

Saturation: Diluting Hues with Gray

One way to change the saturation of a hue *without* changing its value is to dilute it with a gray of equal value. When a pure orange and a gray of equal value are the "parents" in

Figure 4-17.
Hues Diluted by a Gray of Equal Value.

a parent-descendant format, the middle interval, "gray-orange," is duller than the orange, more chromatic than the gray, and identical in value to both: neither lighter nor darker than either of its parents.

Saturation: Diluting Hues with the Complement

A second way to dilute pure color is to add some of its complement. Adding the complement to a color to reduce its saturation is a time-honored technique in subtractive media. When a pair of complements is arranged as a series of hue intervals moving toward each other, each step is reduced in saturation until the two reach a center, where each loses its identity. Complements mixed to this midpoint, where neither hue can be distinguished, become a tertiary color: a chromatic neutral.

Colors diluted in this way change in both saturation *and* value. A subtractive color absorbs more wavelengths of light as its complement is added. This effect is simulated on the screen, in colors of light, somewhat less successfully. Yellow and violet have extreme dark-light contrast, so a series of steps between them is a scale of light to dark as well as a scale of progressively reduced chroma. As the yellow becomes more muted and darker, the violet becomes more muted and lighter. A series between orange and blue displays a similar dark-to-light value pattern, although the value differences are less extreme. Green and red are roughly equal in value, so each becomes darker as it moves toward the other; with the center mix darkest of all.

Theoretical gray is a concept used by color theorists to characterize a perfect tertiary color: one of no discernible hue. Theoretical gray (if it existed) would be created by the mixture of *any* pair of complementary colors. If theoretical gray could be illustrated, the middle mixes of violet and yellow, red and green, and blue and orange would be the same. Visual logic does not allow us to imagine the middle mix of different pairs of complements as the same. Whether a series of steps between complements is illustrated with paints, papers, light, or imagination, every pair of complementary colors moves to a center that is different from other pairs.

Figure 4-18. *Spectrum Hues Diluted by Their Complements.* Each pair reaches a different midpoint.

Some of the most interesting colors result from mixed complements that have been tinted to raise their value. The light neutrals of consumer goods, colors called beige, putty, natural, almond, and so on, are complementary mixes that have been diluted with white.

The natural world is much more a chromatic experience than a black and white one. There are at least 350 varieties of parrots, for example, but only 17 varieties of penguins—and not all of those are "plain" black and white. And although the exuberance of saturated color is easily found—tropical fish, birds, and flowers are examples—muted colors are by far the greatest part of our visual world. Soils and stones, forests, deserts, mountains, rivers, and seas, much of wildlife—all are hues muted by a complement. "Nature shows such mixed colors very elegantly,"[2] says Johannes Itten, as when green fruits ripen to red, or leaves turn from green to brilliant red in the fall.

Tone

There is no really satisfactory definition for "tone." *The Random House Dictionary of The English Language* offers three consecutive (and contradictory) definitions. First, it is defined as "pure color diluted by black or white," which we know as a tint or shade. A second definition states that tone is "one hue modified by another" (as in "this is a blue tone, that is a greener one"). The third meaning is given as "a hue muted by gray." Each definition means a modification of hue, but each means a different *kind* of modification of hue. The first means dilution by changing value, the second means dilution by changing hue, the third dilution by adding gray.

One word cannot mean variation in value, hue, and saturation interchangeably. If the word "tone" is to be used at all it is probably best to go with the most-used meaning: a color of reduced saturation. It seems clearest when used as a *verb.* To "tone down" a color means to mute it, to reduce its saturation. That phrase, at least, is familiar. No one ever says "tone up."

Endnotes

1 *Random House Dictionary of the English Language* 1967, page 1466.
2 Itten 1970, page 50.

Chapter 4 Highlights

- Names for colors are codes for similar sensations. A color is called by the name of its most obvious, or dominant, hue. Each name represents a family of closely related hues. The vocabulary of color includes words that describe interrelationships between colors as well as names for them.

- The basic qualities of colors are hue, value, and saturation, or chroma. Hue means the name of the color. The word "color" is also used more generally to mean the complete experience of hue, value, and saturation. Only six names are needed to describe hue: red, orange, yellow, green, blue, and violet. Black, white, and gray are achromatic.

- The artists' spectrum illustrates the full range of hues in spectral order. Red, yellow, and blue are the primary colors of the artists' spectrum. They are the simplest hues and cannot be broken down visually into other colors or reduced into component parts. Green, orange, and violet are the secondary colors of the artists' spectrum. Each secondary color is an even interval between two primary colors and has one primary in common with each of the others. An expanded spectrum includes the intermediate colors yellow-orange, red-orange, red-violet, blue-violet, blue-green, and yellow-green that are the midpoints between the primary and secondary hues. Many times these colors are referred to, incorrectly, as tertiary colors.

- A saturated color is a hue in its strongest possible manifestation. A saturated hue contains one or two primary colors but does not include a third primary or black, white, or gray.

- Cool colors contain blue or green. Warm colors contain reds, oranges, and yellows. Warmth and coolness in colors are relative qualities: a given color can be made to appear warmer or cooler relative to another.

- Analogous colors lie between primary and secondary colors. Analogous color groupings contain two primary colors but never include the third. Analogy is a relationship between hues no matter what their value or saturation.

- Complementary colors are hues that are opposite one another on the artists' spectrum. A line drawn across the center of a color circle from any point connects a pair of complementary colors. Each complementary pair includes the three primary colors in some mix or proportion. The basic pairs of the artists' spectrum are red and green, yellow and violet, and blue and orange. In each pair one half is a primary color and its opposite is the secondary made of the remaining two primaries. The complementary relationship between hues is maintained no matter what their value or saturation.

- Tertiary colors are chromatic neutrals made of all three primaries. “Brown” is used to describe many of these colors. Brown is not a hue.
- Value refers to relative light and dark in a sample. White is the highest possible value. Black is the lowest possible value. Value contrast exists whether or not hue is present. A value scale is a series of steps between the poles of dark and light. A monochromatic value scale is a single hue illustrated as a full range of values.
- Only value contrast makes objects distinguishable from their background. The ability to discriminate objects from their background requires no hue. The degree of contrast between light and dark areas determines the strength of an image. The placement of different values relative to one another within an image give it individual identity. In order to transpose an image from one color to another, the placement of values within the two images must be the same.
- A tint is a hue that has been made lighter. Strong tints are sometimes mistaken for saturated colors. A shade is a hue has been made darker. Shades are reduced-hue experiences.
- Each of the six spectrum hues is at a different level of value. Saturated yellow is lightest and saturated violet darkest of the spectrum hues. Determining which of two different hues is lighter or darker than the other is difficult when one hue is warm and the other is cool, and most difficult when the hues are complementary.
- Saturation refers to hue intensity. It is a comparative term that describes the contrast between dull and vivid. The saturation of a hue can be reduced without changing its value by diluting it with a gray of equal value. Adding the complement to a color also reduces its saturation. Colors diluted in this way change in both saturation and value. A color that has been dulled by the addition of its complement but is still identifiable is a muted hue, not a tertiary color.
- Theoretical gray is a concept used by color theorists to characterize a perfect tertiary color: a chromatic sample of with no single discernible hue. If it existed, it would be created by the mixture of any pair of complementary colors. There is no satisfactory definition for “tone.”

5

The Instability of Colors

The Instability of Colors / Color Composition / Ground and Carried Colors / Placement and Color Change / Equilibrium / Simultaneous Contrast / Afterimage and Contrast Reversal / Complementary Contrast / Ground Subtraction / Color and Area: Small, Medium, Large

The same color in two different contexts is not the same color.....This means that the identity of a color does not reside in the color itself but is established by relation.

—Rudolf Arnheim

Color is an experience of pure light, as insubstantial and unstable, fleeting and changeable, as a breath of air. Even the achromatic "colors"—grays, blacks, and whites—can alter when there is a change in where they are seen or how they are arranged. Unanticipated color changes can be costly as well as disconcerting. There are real implications for vendors when a color that has been selling well becomes unappealing when it is included as part of a new palette, or when companion products like wallpaper and fabric fail to sell because they do not coordinate when they move from the design studio to a retail setting. The ability to anticipate the sometimes startling changes that take place in colors when they are arranged in different ways, or placed in different settings, and to adjust for them as far as it is possible, is a critical skill for design professionals.

The Instability of Colors

Changes take place in colors for two very different reasons. The first lies in the relationship between colorants and light. Any change in ambient (general) lighting has the potential to alter the appearance of colors. *Changes in ambient lighting affect subtractive colors only*. Additive colors do not change if there is a change in room lighting. They are wavelengths of light that reach the eye directly from an independent source, like a monitor screen or a traffic light. Screen images (or traffic lights) maintain their hues and hue relationships in daylight, under sodium lamps, incandescent lamps, or any other general lighting. Additive colors are stable under any ambient lighting as long as their source remains stable. They may be sensed as brighter overall in a dark area than in a well-lit one, but the hues, and their relationships to each other, do not change.

Arrangement is the second cause of color instability. Each time that two or more colors are used together the possibility exists that one or more will undergo a shift in hue, value, saturation, or some combination of these because of its placement relative to the others. Color shifts caused by a change in lighting conditions are difficult to manage because products and print media are moved from place to place. But the ways in which colors influence each other by placement are predictable and can be controlled by the designer. *Because placement affects both subtractive and additive colors, it has relevance to every step of the design process, from the first sketches, through computer rendering, to the finished product.*

The concept that every color is subject to being changed by its placement is perfectly expressed by Josef Albers' phrase "interaction of colors." No color is seen alone. Even an object that seems at first to be a single color is vulnerable to change from color interaction, because no color is seen without background. The Vermont barn that is red against green in summer is red against white in winter.

Understanding how colors affect and change each other is more than just a way of anticipating and preventing problems. There is a positive aspect to this instability. Two or three colors can be made to seem like three, or four, or even more, by manipulating their placement. In some kinds of printing, for example, the number of colors is a factor in pricing: the more colors, the higher the production cost. A skilled colorist can make two or three colors seem like many more by placing them strategically against each other. The interaction of colors offers opportunities to fine-tune color combinations in ways that add vitality and interest to color compositions.

Color Composition

A *composition* is something made up of individual parts that have been arranged in such a way that they are understood as a single, complete idea. An essay is made of separate words; a song is made of single notes. A composition is understood as separate from its setting and from other things around it. A *design composition* is a planned arrangement of forms and colors meant to be sensed as a single visual idea. Colors used together create a *color composition: a group of colors meant to be sensed as a whole.*

A group of colors selected for use together is called (depending on the industry or design discipline) a palette, a colorway, a color story, or some other collective term. Selecting print, screen, or product colors really means creating a color composition, which can be a first step in the design process or a final one. Forms, colors, and their arrangement have equal importance in design. There are no rules about what must come first.

Figure 5-1.
Color Composition. A carpet design produced in different colorways offers a single pattern as different color compositions.
Carpet design by David Setlow. Image courtesy of Stark Carpet.

Ground and Carried Colors

The background of a color composition is its *ground*. Different industries use different terms for the materials that are used as grounds. Colors printed on fabric or wall covering, for example, are said to be printed on a ground. The background of a carpet or a banner is called the *field.* The paper used in printing is called *stock*. A printer asks if printing will be done on white or colored stock, or on coated or uncoated stock. The monitor screen is also a ground; an empty picture plane waiting for images and colors.

No matter what word is used, “ground” means the background when color relationships are discussed. Colors laid on a ground are *carried colors*. The ground may be an accidental or unconsidered element—a blank white paper or an empty screen—but it is always a factor in the final composition. *Ground establishes the visual reference point for carried colors. It is a critical element in color compositions that is often overlooked.*

The ground is not necessarily the largest area in a composition. The area in a design that is ground is determined by the arrangement of forms, not by color or relative area. Visual cues determine which part of a composition is identified as image or pattern and which part is understood as background.

Negative space is the area within a composition that is not part of the image or pattern. It is the unfilled area around, and sometimes within, the design elements. Negative space is often, but not always, the same area as the ground.

Figure 5-2. *Ground and Area.* Ground is not necessarily the largest area in a composition.

Figure 5-3. *Shaky Ground.* Is a tiger black with yellow stripes, or yellow with black stripes?

In some kinds of patterning it can be difficult (or even impossible) to decide which part of a design is ground and which is carried color. A checkerboard has no identifiable ground; neither does the coat of a tiger. It is not necessary for ground to be a clearly defined area. *Colors will interact whether the ground is obvious or uncertain.*

Placement and Color Change

Three different kinds of color interaction cause apparent change in ground-and-carried-color situations: simultaneous contrast, complementary contrast, and ground subtraction.

All three serve to intensify the differences between colors. *All three are involuntary responses of the eyes, and all three occur in both subtractive and additive color compositions.*

Equilibrium

Equilibrium is a physiological state of rest that the eyes seek at all times. The eyes are at rest when the primary colors of light—red, green, and blue—are within the field of vision. The artists' primaries red, yellow, and blue reflect these wavelengths, as do the process printing primaries cyan, magenta, and yellow. The presence of any of these sets of primary colors in the visual field will bring the eyes to a state of equilibrium.

Figure 5-4. *Equilibrium.* The presence of three primary colors in any form allows the eyes to be at rest. *This is Elizabeth Eakins' carpet design "Sea Ranch"©1993.*

It is not necessary for the primaries to be present as individual colors for the eye to reach a state of rest. Any number of combinations and mixtures will allow the eyes to reach equilibrium: three primaries, or a pair of complements, or two secondary colors, or a hue diluted by its complement (a tertiary color). The three colors do not have to be equal in area. A green tree with one red apple is as effective in providing equilibrium as a red-and-green checkerboard.

Equilibrium is reached most easily when the primaries are mixed together into muted hues. The slightest dulling of a pure color makes it less stimulating to the eye. The popularity of "earth" colors, which are hues muted by the addition of their complement, may derive from the fact that they are genuinely, physically, restful. The eyes will always seek the most physiologically comfortable pathways in color perception.

Simultaneous Contrast

Simultaneous contrast is an involuntary response that takes place when the eyes are *not* at rest—when only a single hue is present in the field of vision. In this situation the eyes work to generate the missing complement, which appears as wash of hue in any nearby achromatic

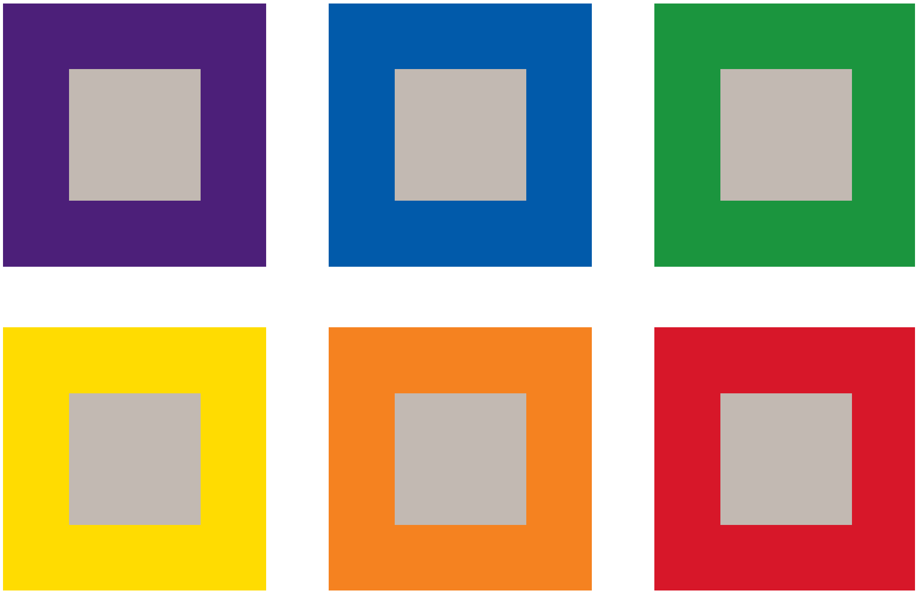


Figure 5-5. *Simultaneous Contrast.* The strongest effects of simultaneous contrast occur when a neutral area is surrounded by a stimulating hue. All of the gray squares are the same. What hues can be seen in them?

area. If a single primary color is present, the missing secondary appears. If a secondary is present, the missing primary appears. *For any given color the eye spontaneously and simultaneously generates the missing complement.*

The effect of simultaneous contrast is most apparent when the stimulating hue is a saturated color or brilliant tint, but muted, tinted, or darkened hues will also cause it to take place. *Simultaneous contrast will occur to some extent whenever a single hue is placed on, or next to, an achromatic area.*

Colors and grays interact in real life exactly as they do in the classroom. If the possibility of simultaneous contrast is not anticipated, the results can be disastrous. A true story illustrates how costly this can be.

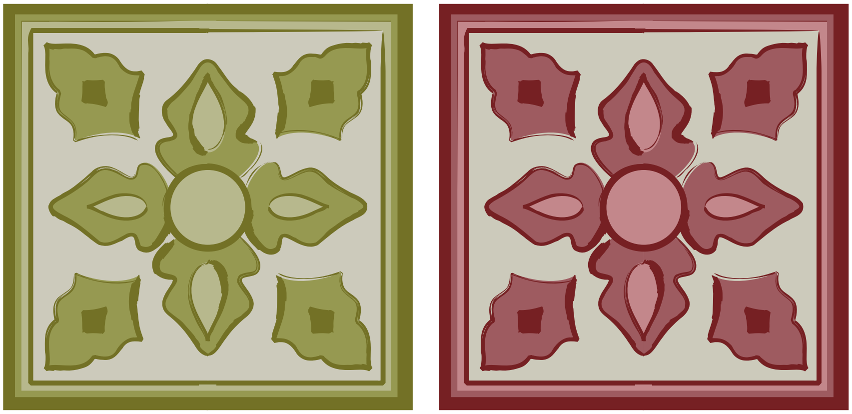


Figure 5-6.
Simultaneous Contrast. Muted colors have a reduced, but still definite, influence on neutrals. The same neutral ground shifts from cool to warm when the carried colors are changed.

An interior designer and his client selected a gray carpet for installation throughout an apartment. The client had been specific, insisting, "I hate blue, I only want gray." The apartment walls were painted "peach" and "terra cotta"—or, more accurately, tinted and muted variations of orange. When the carpet was installed, it was a pale, but definite, blue. The frantic designer brought a sample of the carpet back to the carpet showroom, insisting that the wrong goods had been installed. The sample was identical to the original selection. Simultaneous contrast was the villain. The orange-based wall colors caused the eye to generate the complementary blue, and the expanse of gray carpet was the perfect neutral field on which the complementary blue could be seen.

Simultaneous contrast is a factor in the selection of every neutral (including, and especially, variations of white) that is intended for use with a single hue or close family of hues. Fortunately, it is not difficult to anticipate and counteract unwanted effects. If a green textile is used with a white one, adding a slight green undertone to the white counteracts the red that the eye generates. Without that green, the white takes on a pink cast. A red textile calls for the opposite—a red undertone in the white to counteract the green that the eye supplies. If the designer in the example had used a gray carpet with a warm orange undertone, the problem would not have occurred.

Nearly all situations in which three primaries are present in the visual field allow the eye to be at rest, but compositions with blocks of very brilliant colors can be an exception. Vivid hues used together can at times deliver such strong, separate, and contradictory stimuli that the eyes respond to each as if it were a single sensation. The struggle to maintain equilibrium means that the eyes must work, and work hard. The resulting eye fatigue can lead to genuine discomfort, like headache or blurred vision.

Afterimage and Contrast Reversal

Afterimage, or *successive contrast,* is exactly what it sounds like: an image that appears *after* a stimulating hue is taken away. Afterimage is caused by the same response of the eye as simultaneous contrast but takes place under different conditions. Simultaneous contrast can be induced by a brilliant color or a muted one, and the achromatic area that it affects must be adjacent. Afterimage requires a brilliant color stimulus and a nearby, but

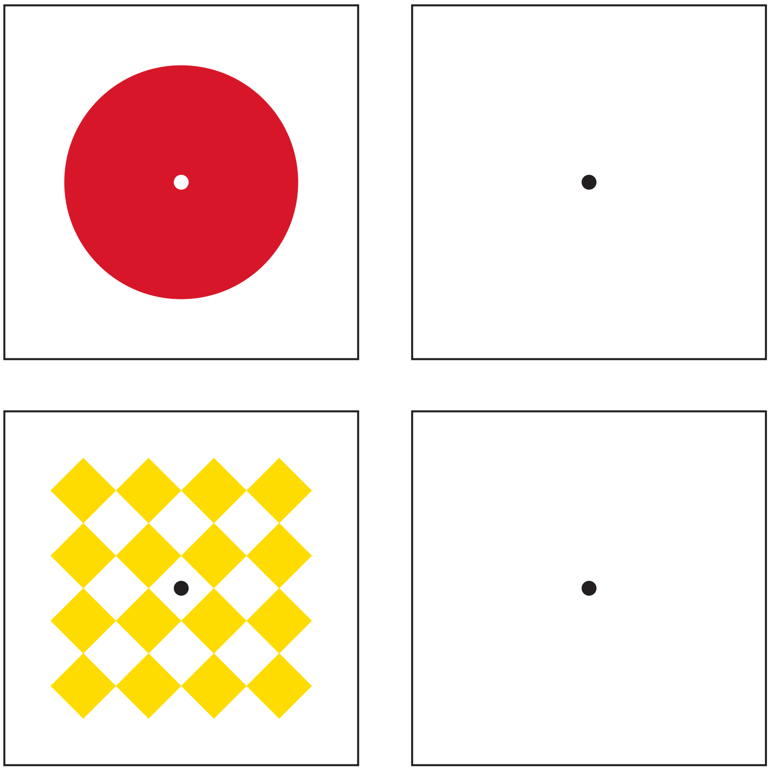


Figure 5-7.
Afterimage. Cover the lower half of the illustration with white paper. Stare at the red circle as long as possible without blinking. Blink firmly, then look immediately at the black dot in the center of the white square.

Next, cover the upper half of the illustration and repeat the exercise with the diamond design. What happens?

separate, blank white or light surface. The viewer stares hard at the color image, then blinks firmly and looks immediately at the white surface. The image appears ghost-like on the blank area—in complementary colors.

Contrast reversal is a variation of afterimage. In contrast reversal the "ghost" appears as a sort of double negative, with both complementary colors appearing, and in reversed positions. A stimulating pattern might be bright yellow diamonds on a white page. When the image is removed and a white field substituted, pale violet diamonds appear in place of the yellow ones, and the white spaces between them are faintly yellow.

Afterimage also occurs without hue. A black and white illustration viewed in this way will appear with the values reversed, like a photographic negative.

Complementary Contrast

Complementary contrast describes what happens when two colors with a complementary relationship—even the slightest complementary relationship—are used together. Simultaneous contrast takes place when only one hue is present. *Complementary contrast intensifies the difference between two hues that are already present, and already different.* Complementary contrast occurs with every form of color: saturated color, tint, shade, or muted hue.

Figure 5-8. *Complementary Contrast.* Complementary colors are emphatically different when they are used together, but neither changes the other.

A saturated color is seen at its maximum hue intensity when it is paired with its complement (or a near-complement). The difference in hue between the two is emphasized, but neither color undergoes any *change*. Red used with green remains red and green remains green; blue and orange together remain blue and orange, and so forth. This is true for saturated colors that are opposite at all points on the spectrum, not just the primary-secondary color pairs. The intensity of any hue is enhanced by the presence of its complement. Red-violet is brilliant on its own; add a patch of yellow-green and it positively sings.

The second aspect of complementary contrast is its power to bring out undetected hue. It is with muted hues and their tints and shades that the hue-intensifying power of complementary contrast has its greatest impact. Complementary contrast does not require a brilliant stimulating color. A sample may seem so pale, or so dark, or so dull, that it seems achromatic, but when placed with its complement, or *a color that contains some of its complement*, previously unseen hue becomes suddenly visible. When both halves of a complementary pair are muted, *each* seems to become more hue-intense and more different from the other. No matter how slight, how muted, how "barely-there" the complementary contrast between two samples, the hue difference between them is intensified when they are placed together.

Goethe described the complements as "completing colors."[1] The basic complementary pairs, each made up of a primary and secondary color, are the foundations of complementary contrast. Colors do not have to be exact opposites for complementary contrast to occur.

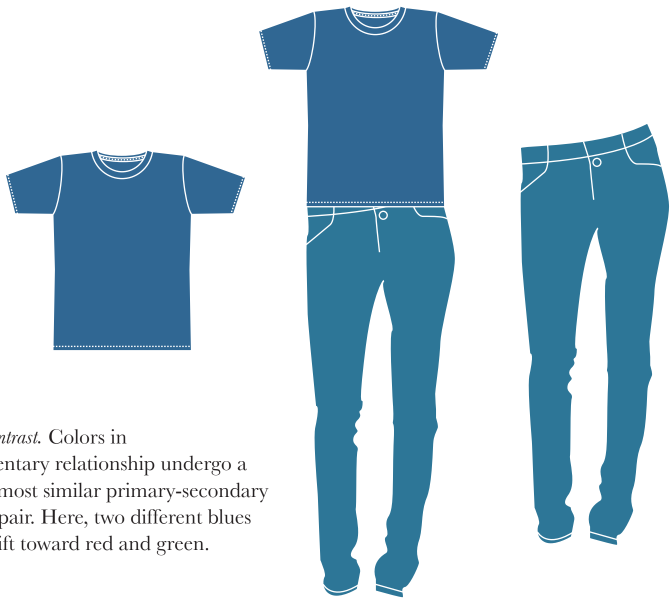


Figure 5-9.
Complementary Contrast. Colors in a part-complementary relationship undergo a shift toward the most similar primary-secondary complementary pair. Here, two different blues used together drift toward red and green.

They can be near-complements (or part-complements) like red-orange and green, or yellow-green and violet. *When colors other than the primary and secondary pairs are in a complementary (or part-complementary) relationship, they undergo a shift in hue toward the most similar primary-secondary pair.* Two "navy blue" samples, placed together, may suddenly appear greenish-navy and purplish-navy. The hue contrast that becomes visible is the red undertone of one and the green undertone of the other. *The eye seeks not only equilibrium, but also the simplest and most "completing" hue relationship.*

Ground Subtraction

Simultaneous contrast and complementary contrast are responses of the eyes to the complementary relationship. Each intensifies differences between samples that are already unlike. *Ground subtraction* is completely different. It takes place when a ground and its carried colors have *qualities in common—and also qualities that are different.* Whatever qualities that are shared by a ground and its carried colors are reduced; at the same time, differences between them are emphasized.

Figure 5-10. *Ground Subtraction of Value.* A middle gray appears darker on a light ground and lighter on a dark one.

For example, a middle gray placed on dark gray appears lighter: the darkness that is common to both is reduced and the remaining lightness intensified. The same middle gray placed on light gray appears darker. The lightness it shares with its ground is reduced, while the remaining darkness is emphasized. It is the "like-unlike" relationship between the ground and carried colors that generates change.

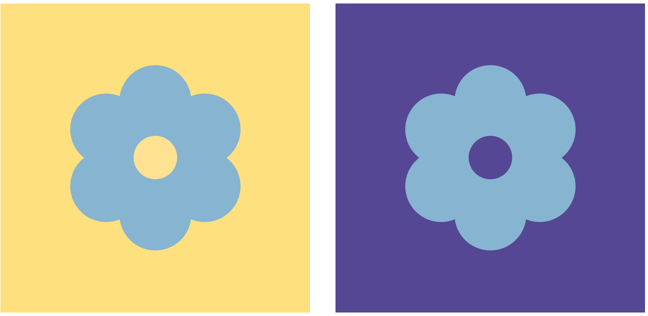


Figure 5-11. *Ground Subtraction of Value.* The same blue appears darker on yellow and lighter on deep violet.

The effect of altered value is the same when hue is present. A middle-value blue placed on yellow-orange appears darker than the same blue placed on spectrum violet. *Any ground subtracts its own qualities from colors it carries. The more similarities a color has with its ground, the more apparent their differences will be.*

Figure 5-12. *Ground Subtraction: One Color as Two.* Colors appear to change when they are placed on grounds that share different aspects of the own qualities.

In theory, primary colors will not change in hue by placement, although they can be altered in apparent value. Secondary and intermediate colors (and all hues between them) will change, at times quite dramatically, when they are placed on grounds that share *different* aspects of their own qualities. Red-orange appears more yellow-orange by placing it on red (the common red is subtracted), or more red by placing it on yellow-orange (the common yellow is subtracted).

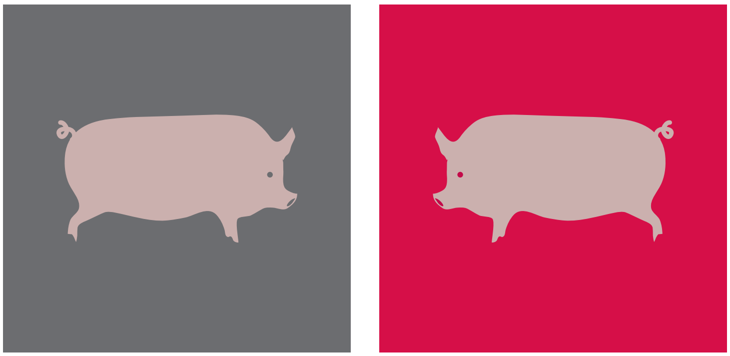


Figure 5-13. *Ground Subtraction of Hue.* A red-gray placed on gray appears more red. Placed on red, it appears much grayer.

The difference between the two carried colors seems even greater because both hue and value are affected. The red-orange appears lighter on the red; darker on the yellow-orange.

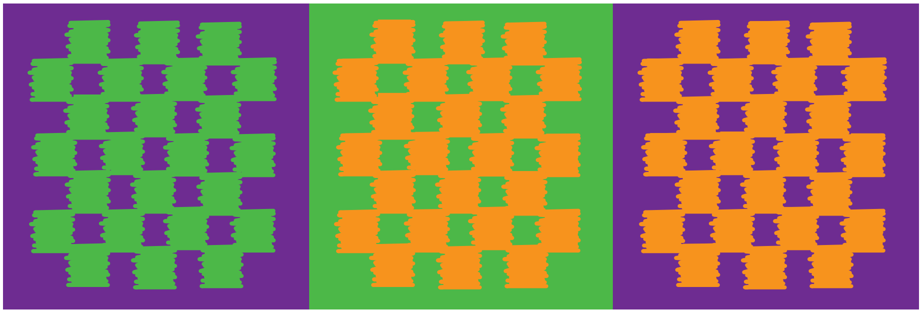


Figure 5-14. *Ground Subtraction of Hue.* How many colors are actually printed?

A muted color is more vivid on a grayed ground and more muted on a chromatic one. When a mix of gray and a brilliant hue is placed on each of its "parents," the mix seems very gray on the vivid ground; brighter and more chromatic on the gray one.

The more complex a color is—the more elements it contains—the more likely it is to be affected by colors around it. The changes that take place in complex colors are not necessarily more dramatic than those that take place with simpler colors. Change is simply more *likely*, because the more "ingredients" that are present, the greater the number of possibilities that it will have elements in common with (and also different from) its ground. A neutral "beige" mixed from blue, orange, and white can be made to appear duller or brighter, darker or lighter, more cool (or blue) or more warm (more orange) by placing it on different grounds.

Figure 5-15. *Ground Subtraction: Two Colors as One.* Different colors can be made to seem the same by placing them on grounds of opposing qualities.

Finally, color shifts can be extreme when *both* ground subtraction and complementary contrast are in play. If a brown square, made of a mixture of blue and orange, is placed on an orange ground, the orange component that is common to both is reduced by ground subtraction. The blue is strengthened twice: first, as the color remaining after the orange is reduced, and again by complementary contrast against the orange ground. The same brown square, placed on a blue ground, looks very much more orange. The orange component is made stronger twice: first, as the color remaining after the blue is reduced, then by complementary contrast against the blue ground.

The principle of ground subtraction can be used in reverse to make different (but similar) colors appear to be identical. A green and a yellow-green can be made to look the same by placing them on grounds of *opposing* qualities. Yellow-green placed on yellow appears more green; the common yellow is reduced. Green placed on blue-green appears more yellow; the blue that is present in both is reduced.

Color and Area: Small, Medium, Large

A different kind of shift takes place in subtractive colors when a color that has been selected from a small sample, like a paint chip or fabric cutting, is applied to a large surface. The direction (placement in space) of a large color plane affects whether it will read as lighter or darker; or more muted or more chromatic, than it does as a small chip. Changes of this kind are not color interactions. They are differences seen in a single color, under the same lighting, but in different extents.

Typically, light reaches surfaces from above and at an angle. When light reaches a wall surface or a floor from the conventional direction, floors and walls appear lighter, and ceilings darker, than a small sample of color in the hand. The *quantity* of light reflected from a large surface is greater than the quantity of light reflected from a small sample. Charcoal gray, near-black on a paint chart, becomes a medium gray when applied to the exterior of a house. Carpet, medium beige in a small cutting, becomes lighter on the expanse of a floor. Conversely, a color selected for a ceiling must be made two or three steps lighter than a small sample to achieve the same effect, because less light that is directed conventionally—down from above—reaches a ceiling.

Colors also appear more *chromatic* on a larger plane. The presence of hue in chromatic neutrals (like "beige") is more visible in larger scale. Light and dark colors are equal in this.

An apparently neutral dark brown applied to a large wall is seen as both lighter and more chromatic — more red-brown, or more orange-brown — than in a small paint chip. A color experienced as "pale ivory" in a sample may read as true yellow on a large plane. A vivid color, mindlessly cheerful in a small dose, can be overwhelming as a painted wall. Adjusting a color selection to compensate for the difference between a small sample and the same color in a large area is an issue faced more in architecture and interior design than in other design fields.

Endnotes

1 Goethe 1971, page 55.

Chapter 5 Highlights

- Any color can alter when there is a change in how or where it is seen. Any change in general lighting has the potential to alter the appearance of subtractive colors, but does not change additive colors. Whenever colors are used together one or more may appear to change because of its placement relative to others. Changes in placement affects both subtractive and additive colors.

- A color composition is a group of colors meant to be sensed as a whole. The background of a color composition is its ground. Colors laid on a ground are carried colors. Ground establishes the visual reference point for carried colors. The area in a design that is the ground is determined by visual cues. Negative space is the area within a composition that is the unfilled area around or within the design elements. Negative space is often, but not always, the same area as the ground.

- The eyes constantly seek a state of rest, or equilibrium. Equilibrium is reached when the primary colors of light; red, green, and blue, are within the field of vision. Any number of combinations or mixtures of the primary colors will allow the eyes to reach equilibrium.

- Simultaneous contrast means that for any given color the eye spontaneously and simultaneously seeks its complement. Any adjoining achromatic area takes on aspects of that complement.

- Complementary contrast intensifies any complementary relationship that exists between a ground and a carried color.

- Ground subtraction takes place when a ground and carried colors contain elements in common as well as elements that are different. Qualities that are shared are reduced and differences between them are intensified.

- Different (but similar) colors can be made to seem identical by placing them on grounds of opposing qualities. The more complex a color, the more subject it is to change by placement.

6 Illusion and Impression

Optical Illusions / Color Illusions / The Illusion of Depth / Spatial Effects of Colors / Transparence Illusion / Fluting / Vibration / Vanishing Boundaries / Luminosity / Bezold Effect / Optical Mixes

Reality is an illusion, albeit a very persistent one.

—Albert Einstein

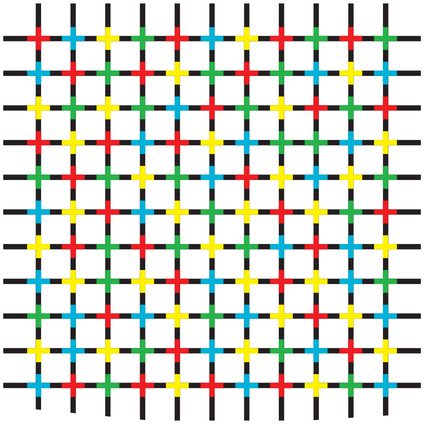
An optical illusion is a seemingly magical event that takes place when an image is misperceived or misinterpreted by a viewer. An illusion can only be *seen*. It cannot be confirmed by physical measurement or by any of the other senses. It is a purely visual experience that is mistaken for an objective reality.

Optical Illusions

The simplest illusions are initiated by involuntary responses of the eyes to overstimulation by something specific, like a single hue or extreme contrast. Afterimages and the color shifts caused by simultaneous contrast, complementary contrast, or ground subtraction are examples of this kind of direct response. Other aspects of vision, like lateral inhibition or involuntary eye movements, can also play a part. Traditionally, these have been considered to be illusions with a *physiological* basis. Illusions have traditionally been considered *cognitive* (knowing) when they take place because the observer makes unconscious assumptions or inferences about something when the actual image is different.

Seeing requires an elaborate interplay between the eyes and the brain. More complex illusions occur because an image is interpreted by a brain that is processing visual

Figure 6-1.
The Importance of Arrangement. In an illusion called neon color spreading, small areas of brilliant color are introduced into a repetitive pattern of black lines on a white ground, and the color seems to spread into the white space.



information—and processing it inaccurately. The current thinking among vision scientists is that *all* illusions have a physiological basis. All are caused by a disturbance to the flow of information between the eyes and the brain, although some engage more of the reasoning parts of the brain than others.

No matter how it originates or what it is called, every illusion takes place within a limited set of circumstances. Illusions depend on more than interaction between the human eye and brain. They depend equally on the *arrangement* of design elements: forms, lines, and colors.

Color Illusions

Color illusions occur when colors that have specific relationships are arranged in ways that mislead the eyes. Color illusions exemplify the current view: they are both a physiological response to and an interpretation (or, more accurately, a misinterpretation) of what is seen.

A true illusion fools the eye absolutely, and many effects that are called illusions do not meet this standard. Some, like an impression that printed colors are glowing on a page, might more accurately be called special effects, or even near-illusions. But no matter what a deceiving image is called—an illusion, a near-illusion, an impression, or a special effect—each has the same requirements: a set of colors with specific qualities and interrelationships, and that these colors be arranged in a particular way.

The Illusion of Depth

Whether a drawing is destined for print or a Web page, a great deal of graphic art is concerned with communicating three-dimensional objects—cars, soda bottles, articles of clothing, buildings—on the two-dimensional plane of a page or screen. An illustration of depth on a two-dimensional surface is not an illusion. Even the most skilled drawings that indicate depth are understood as *representing* three dimensions, without any expectation that the depth will be seen as real. An illusion of three dimensions takes place only when a two-dimensional image is sensed by the observer as having actual depth. These illusions, made possible by technology, are a bridge between drawing and the real world.

Real-world depth perception depends first on binocular vision, or using two eyes. Only width and height are seen directly. Each eye receives two-dimensional information from a slightly different position and sends a slightly different image to the brain, which interprets the two messages as a three-dimensional situation.

Depth perception also depends on the assumptions of *perceptual constancy*. Perceptual constancy means that things are understood as remaining the same even as the eyes receive changing images. A familiar object seen as very small is understood to be farther away, not as reduced in size. Perceptual constancy provides important information, called *depth cues*, that complete the information provided by binocular vision.

Impressions of depth on a page or screen are created by using one or more of a set of drawing conventions called *pictorial depth cues*. Some important pictorial depth cues are overlap, linear perspective, shading, shadow, texture gradients, and atmospheric perspective.

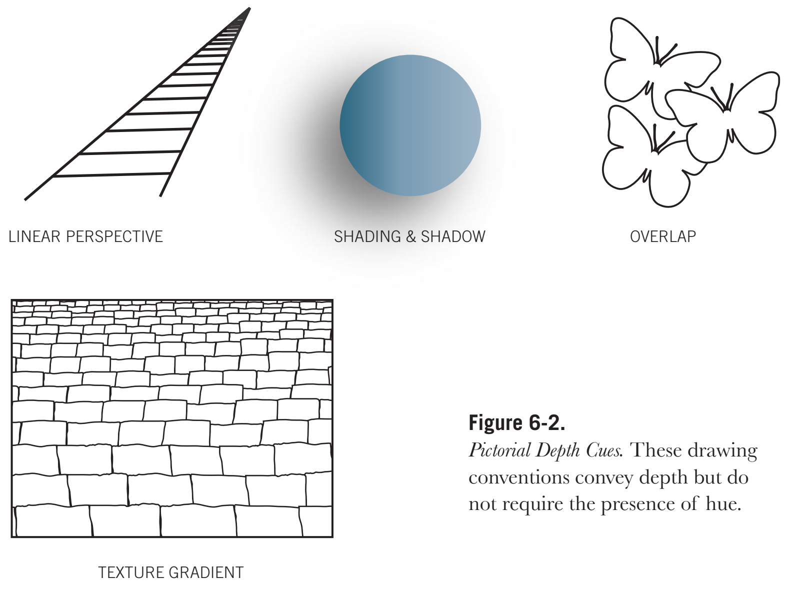


Figure 6-2.
Pictorial Depth Cues. These drawing conventions convey depth but do not require the presence of hue.

Atmospheric perspective (or *aerial perspective*) is the only pictorial depth cue that has a hue component. The farther away an object is in the real world, the more air and dust intrude between it and the observer, so that faraway objects appear less distinct. And, because the atmosphere scatters more of the blue wavelength of sunlight than the other colors, distant objects also appear slightly bluer than closer ones.

Figure 6-3. *Atmospheric Perspective.* Air and dust blur distant contours, making them increasingly indistinct. Scattering of the short wavelengths of sunlight by the atmosphere makes them appear slightly bluer. *Photograph by Gwen Harris.*

The more information—the more pictorial depth cues—provided by a drawing, the more convincingly three-dimensional objects can be represented. Unmoving images are limited to depth cues that represent three-dimensional space. They do not fool anyone into mistaking them as three-dimensional. It is always clear that the surface is flat. In order for an image to be perceived as three-dimensional on a two-dimensional plane, the additional depth cues of time and motion are needed.

Motion parallax (or *movement parallax*) is a real-world depth cue that includes motion and time. When a viewer is in rapid motion, near objects appear to move by in a blur while far objects seem to move slowly. Distant signs can be read from a moving train, but signs close to the track pass too quickly to be read. Objects are understood to be closer or farther away by a comparison of how fast they seem to move relative to the observer's position. Unlike a page, a screen image can include both motion and time. Motion parallax is a depth cue that can be simulated on-screen.

Motion graphics are drawings that include pictorial depth cues, motion, and time. Motion graphics can be magical. One additional element helps to complete the illusion of an alternate reality. *The most convincing illusions of depth result when a full array of depth cues is reinforced by the spatial effects of colors.*

Spatial Effects of Colors

One way to characterize the nature of colors is to think of them in terms of "near" or "far." Some colors have inherent qualities of "nearness" or "farness." Light blues seem to move away, and warm colors of any value close in. But in color compositions, the hue, value, and saturation of each form *in relation to its ground or surrounding colors* influences whether it is perceived as advancing or receding in space. Independent objects (and drawings of them) can be made to appear nearer or farther away by making changes in their hue, value, or saturation.

In general:

> *Hue*: Warm hues advance relative to cooler ones. Reds, yellows, and oranges appear to come forward relative to blues, greens, and violets.
>
> *Saturation*: Brilliant colors (saturated colors and strong tints) appear to come forward relative to muted colors or grays.
>
> *Value:* In a simple image of a figure against a ground, the figure will advance no matter whether it is lighter or darker than its background. A dark figure will come forward on a light ground and a light figure will come forward on a dark ground.

This interpretation of "near and far" is an aspect of visual processing called *figure-ground perception*. Figure-ground perception refers to the eye's ability to separate images into parts based on the contrast of dark and light: the basic process of seeing. The brain sorts visual information into dark and light areas and determines their edges, then translates this into a determination of which part of the image is figure (meaningful, seen as coming forward), and which is background (less meaningful, seen as receding.)

When figures of different value are laid against the *same* ground, however, the difference between each in relation to the ground determines which will advance and which will recede. *A figure with greater value contrast with the ground will advance and one closer in value to the ground will recede.* The greater the value contrast between a figure and its ground, the more sharply defined and nearer it seems. The depth cue of atmospheric perspective — that forms become less distinct as they move into the distance — signals that less contrasting figures are farther away.

Figure 6-4.
Spatial Effects of Warm and Cool Hues. Warm hues advance relative to cooler ones.

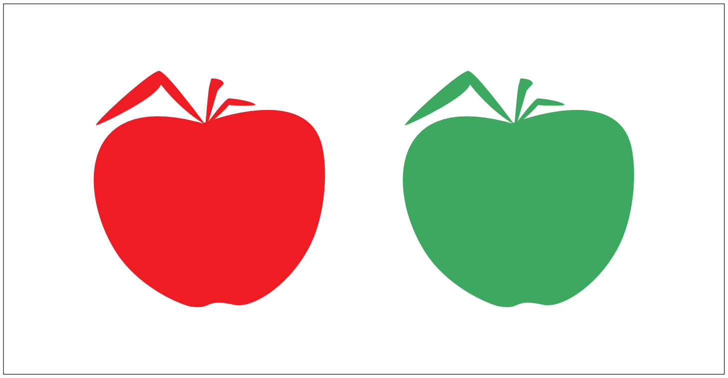


Figure 6-5.
Spatial Effects of Saturation. Brilliant colors come forward relative to muted ones.

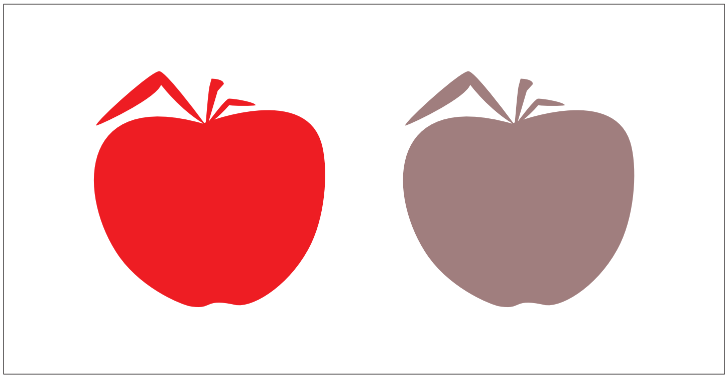
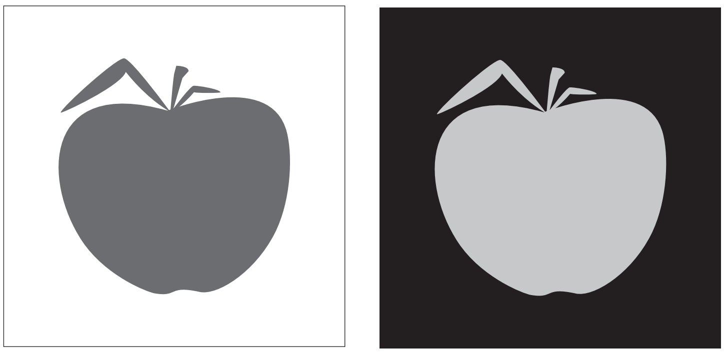


Figure 6-6.
Value and Figure-Ground Perception. A dark figure comes forward on a light ground; a light figure comes forward on a dark ground.



Dark or light color also influences how the size of a figure is perceived. The same object in a light color seems larger than it does in a darker color. A white bear would seem bigger than the black one—standing right in front of you, just ahead on the trail—in the same spot.

Color alone, however, does not create an effect of depth. It is a secondary indicator that supports one or more of the pictorial depth cues. The spatial effects of colors in a drawing can be reduced, or even reversed, by pictorial depth cues. Perspective and overlap, for example, are stronger indicators than color in conveying an impression of three dimensions.

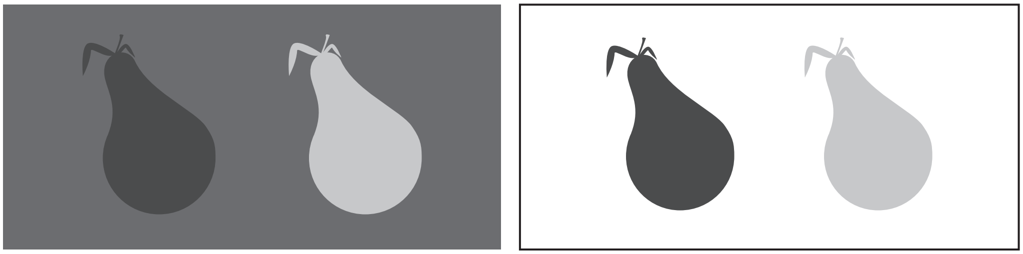


Figure 6-7. *Comparative Value, Ground, and Spatial Perception.* A figure that contrasts sharply in value with its ground advances relative to one that is closer in value to the ground.

The key to understanding whether a colors appears to advance or recede in relation to others lies in the phrase *"all other factors being equal."* Combinations of colors in which all factors are equal except one are rare. The *dominant* quality of a color—its coolness or warmth, high value, or brilliance relative to other colors present—determines whether it seems to move forward or back. In a gray world, yellow bounces forward. In a black world, gray glows with light.

Transparence Illusion

A *transparence illusion* is a three-dimensional illusion that takes place when two opaque colors and an interval between them are arranged in such a way that one color appears to be transparent and lying on top of the other.

A transparence illusion depends equally on two ideas: the pictorial depth cue of overlap and the intervals of a parent-descendant color series. A line drawing of overlapping forms suggests three dimensions; add three intervals of color and the suggestion becomes an illusion.

The guidelines of spatial effects determine which color in a transparence illusion will appear to be on top of the other. A color that is high in value, warm, or brilliant will appear to be on top when paired with a darker, cooler, or duller one. The top color will seem to come forward; the bottom color to recede.

The simplest transparence illusions are illustrated by arranging any two colors and an even interval between them in such a way that the middle interval fills any area where the two overlap. Changing the middle step between the parent colors to an uneven interval affects the apparent transparency of the top color. The more similar the color in the area of overlap is to the bottom (or receding) color, the more transparent the top color will appear.

Transparency in color can be a fact. Transparent liquids appear stronger in hue as their volume increases, a phenomenon Josef Albers describes as "volume color."[1] A strawberry milkshake is opaque, the same color in a gallon container as in a cup. Coffee is transparent. In a deep pot it is

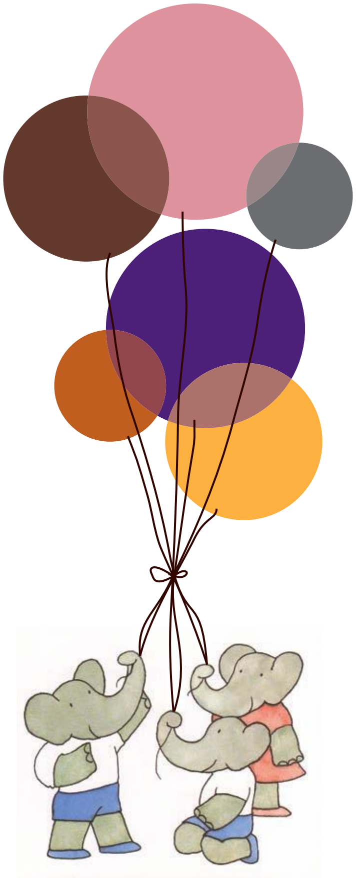


Figure 6-8.
Transparence Illusion.
When a number of colors and intervals between them are arranged in an overlapping way, the effect of transparency follows the guidelines of spatial effects. *Image courtesy of Laurent de Brunhoff. Laurent de Brunhof. Babar's Book of Color. New York: Harry N. Abrams, Inc. 2004*

Figure 6-9.
Transparence Illusion: Hue. If the middle color is an interval between warm and cool parents, the warmer parent color appears to be on top (transparent), and the cooler one underneath it.

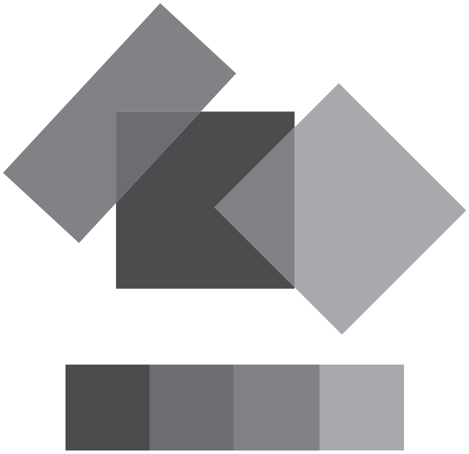


Figure 6-10.
Transparence Illusion: Value. If the middle color is an interval of value between the parent colors, the lighter parent color appears to be on top (transparent), and the darker one underneath it.

Figure 6-11.
Transparency. If the middle color is an interval between chromatic and achromatic parents, the chromatic parent will appear to be on top (transparent) and the achromatic one beneath it.

very dark, but spilled in a saucer it is as light as tea. Some media, like watercolors or four-color process printing inks,, allow light to pass through a colorant and reflect back from white paper underneath. As layers are added, the effect of transparency decreases and the covered areas become deeper in hue. These are true transparencies, not illusions.

Certain hues suggest transparency. Cool hues, especially tints of blue and green, often seem transparent. Hues that are both warm and dark seem more dense and opaque. The medium makes a great difference in whether colors seem transparent or opaque.

Figure 6-12.
Transparence Illusion. Shifting the middle interval closer to one parent or the other alters the apparent degree of transparency of the top color.

Brilliance and transparency are more easily displayed on the screen than on paper, while deep and opaque colors are the reverse: more convincingly shown on paper, more difficult to render in the medium of light.

Fluting

Fluting is a three-dimensional illusion in which a series of vertical stripes of uniform width appear to have concavity, like the channels of a Doric column. Fluting occurs when stripes are arranged in a series of progressive steps of value. Each stripe is an even step of value between the darker and lighter stripe on either side of it. The edges of each stripe appear lighter where it abuts its darker neighbor and darker where it abuts its lighter neighbor. This creates an illusion of shading, the depth cue that give an impression of roundness.

Figure 6-13. *Fluting.* Stripes in steps from dark to light create an illusion of concavity.

Figure 6-14. *Fluting.* Colored stripes arranged in steps of value seem to have concavity.

Like the Three Bears' porridge, the width of the stripes has to be "just right." If the stripes are too wide, the eye cannot take in both edges at the same time. If they are too narrow, they appear to be lines instead of channels. Wide stripes sometimes give an illusion of convexity, but the illusion is still called fluting.

The effect of fluting is not confined to grays. Any hues can be used to create an illusion of fluting as long as they are arranged as a progression of values. When the same colors are configured as random values, the fluting disappears.

Figure 6-15. *Not Fluting.* Colors arranged in random values have no three-dimensional effect.

Vibration

Vibration is an effect that takes place when blocks of brilliant and complementary (or near-complementary) colors that are equal or very close in value are placed together. Combinations like a medium-value tint of blue and a saturated orange, or a tint of blue-green and a deep pink, will appear to shimmer where they meet, and edges between them are difficult to see.

Vibration is an uncomfortable visual experience. The impression of "shivering" color is the result of a potent combination of factors: the difficulty of finding the edge between forms of similar value, the conflict of trying to reach equilibrium in opposing and brilliant colors at the same time, and the effect of natural eye movements called *saccades*.

The eyes are always in search of visual resolution: they want to see clearly at all times. Saccades are involuntary eye movements that occur constantly and rapidly, but human beings are completely unaware of them. To stand and gaze at a painting may feel like a stationary event, but the eyes are constantly moving, finding first the more interesting parts, then putting them together to form a complete mental picture. Each saccade sends a "snapshot" of a small part of the image to photoreceptors (light receptors) in the brain. If the response time of a photoreceptor is different from the time that the area of the "snapshot" is moving across the retina, that small area of vision will blur. The moment is brief—focus returns quickly—but the rapidly alternating blur/focus sensation can be misinterpreted as motion

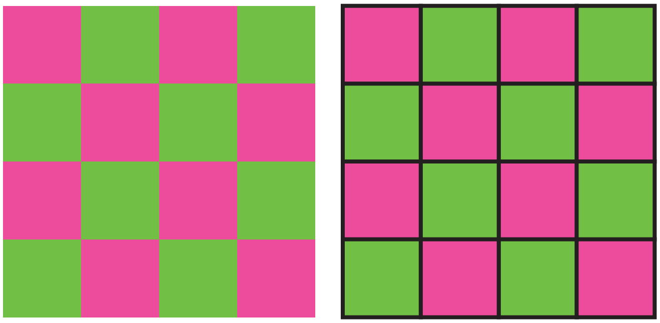


Figure 6-16.
Vibration. A separating line lessens or eliminates vibration.

on the page. The more difficult it is to focus, the greater the impression of movement.

Palettes of brilliant and strongly contrasting hues have an inherent joyfulness, and these color groups are used constantly in many design fields. Vibration occurs only when adjacent colors are very different, very brilliant, and equal or close-to-equal in value. It can be eliminated by separating the colors so that they no longer touch, either by rearrangement or by adding a value-contrasting line between them.

Vanishing Boundaries

Vanishing boundaries occur when areas of *similar* hue and close value are placed next to (or on top of) one another. Vanishing boundaries are a “soft” effect—each form seems to merge into the other and lose its edges. Vanishing boundaries are not uncomfortable in the same way as vibration. The colors involved can be brilliant or muted, but their hues are similar, not opposed. The eyes do not need to seek equilibrium in two different ways at the same time.

Figure 6-17.
Vanishing boundaries.

Luminosity

A difficulty in finding edges also plays a part in another family of illusions: those in which subtractive colors seem to be luminous, or glowing on a page. Like all illusions and impressions, these effects require that colors with specific relationships be arranged in particular ways.

Figure 6-18.
Luminosity. A gradient halo between a light area set into a darker field suggests glowing light.

Effects of luminosity follow the guidelines of spatial effects: Lighter colors move forward relative to dark; more vivid colors move forward relative to dull ones. A glowing light is illustrated *without* hue by setting a relatively small, very light area (of any shape) into a large and darker field, with a "halo" of closely spaced, progressive intervals of value radiating out from the light area into the dark. When the halo is a gradient, or seamless transition from dark to light, the effect is of soft glow. When the halo is a series of intervals just at the threshold of vision, the effect is of a shimmering, light source.

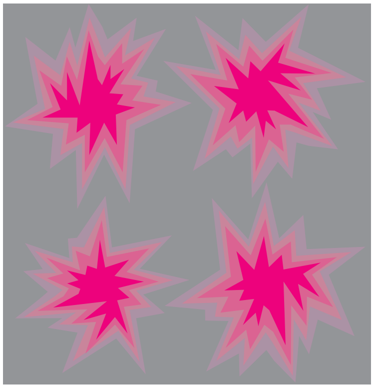


Figure 6-19.
Luminosity. A gradient halo between warm and cool colors creates an impression that color is glowing on the page. *Photograph by Alison Holtzschue.*

Figure 6-20.
Shimmer. A pattern of brilliant color separated from its field by close intervals of saturation seems to flicker on the page.

Dark and light areas arranged in this way *illustrate* glowing light, but a brilliant hue arranged in the same way has a much more dramatic impact: Illusions of luminous hue can be very convincing. To achieve this effect a small area of brilliant color is set into a less chromatic field. The hue can be the same value as its field; it can also be lighter or darker. A "halo" of closely spaced, progressive intervals is set up between the two. If the halo is a gradient between hue and field, the effect is a soft glow. If the progression between the two is a series of intervals just at the threshold of vision, the color seems to shimmer on the page. Irregular drawing at the edges of the intervals reinforces this effect. But as long as a sequence of intervals is close and progressive, and moves from brilliant color to less brilliant color, a luminous effect will take place. Colors arranged in this way can bring subtractive color closer to the brilliance of colored light.

The colors seen on a monitor screen are already made of light, but the light is emitted from the screen overall, so there is no effect that colored light is emanating from a particular location. Colors on a screen must still be arranged in a specific way for an impression of glowing color to take place.

Bezold Effect

Bezold effect, or *spreading effect*, describes what happens when the value of an entire composition is altered by adding, removing, or changing one color only. Unlike most illusions and special effects, it is an effect of *line.* It takes place when internal design elements are outlined, or separated from the ground by dark or light line. When the forms are enclosed by dark line, all colors appear darker. When the forms are enclosed by light line, all colors appear lighter.

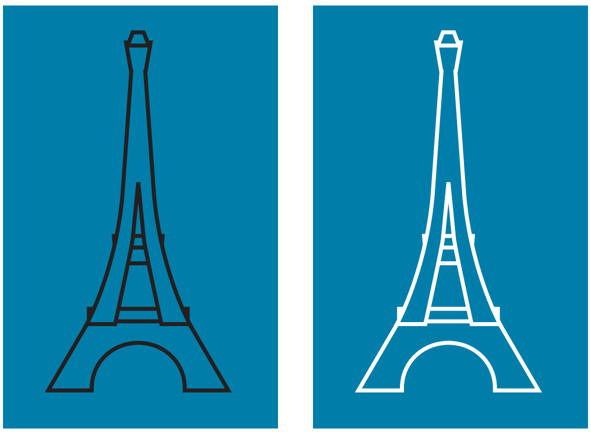


Figure 6-21.
Bezold Effect. When forms are enclosed by dark line, all colors appear darker. When the forms are enclosed by light line, all colors appear lighter.

The dark or light outline affects the apparent value of the entire composition. The presence of a dark or light outline changes only the perception of the overall value of a composition. Hue and saturation are not affected. Because every image, black and white or color, is created by the placement of different values within it, changing a *block* of color from dark to light (or the reverse) creates a new and different image—not a lighter or darker version of the original.

Optical Mixes

An *optical mix,* or *partitive color*, is created when two or more colors, in tiny masses or patches just at the threshold of vision, are used together to create a wholly new color. The color masses in an optical mix are so tightly configured that they are very difficult to distinguish as individual elements, but they do not entirely blend. Optical mixes are sometimes called *retinal mixes* because color is mixed in the eyes, not in a jar or on a palette.

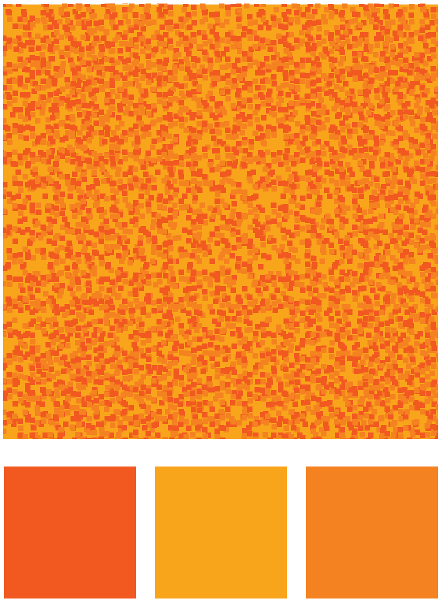


Figure 6-22.
Optical Mixing. Optical mixes depend for their final effect on the color elements that are used together.

The success of an optical mix depends on the size of its color masses relative to the distance from which the whole will be ordinarily be seen. If the elements are too large, the colors read as separate patches. Too small, and the surface becomes as smooth and featureless as flat paint. Designing graphics for a telephone directory, for example, assumes a close viewing distance. Designing wallpaper presupposes a middle distance, highway billboards another viewpoint entirely: the “dot” in an optical mix on a billboard may be the size of a dinner plate when it is seen at close range.

Optical mixes have a vitality that flat color cannot offer. The hue, value, and saturation of each patch of color contrasts with its neighbors according to the guidelines of spatial effects. Some patches advance and some recede; others create a "ground" of sorts, a matrix for the advancing and receding elements. An optical mix of brilliant analogous colors is dynamic and lively. Complementary colors mixed as dots just above the threshold of vision appear as a muted color or neutral, depending on the proportions of the colors. A blending of dark, light, and middle values create an impression of texture.

Optical mixing that is *below* the threshold of vision plays an enormous role in industry and design. The new colors created in this way are without texture or movement. Most color printing is achieved by the optical mixing of process colors. Dots of cyan, magenta, yellow, and black inks, too small to be seen without a magnifying glass, merge in the eye to create new colors. The colors on a monitor, too, can be described as a kind of optical mix. Thousands of tiny, individual dots of red, green, and blue light, additively mixed, create the hues, tints, and shades of the screen display.

Endnotes

1 Albers 1963, page 45.

Chapter 6 Highlights

- An optical illusion takes place when an image is misperceived or misinterpreted by a viewer. True illusions fool the viewer completely. Many effects that are called illusions are more accurately special effects or near-illusions.

- Simple illusions are initiated by involuntary responses of the eyes to overstimulation by something like a single hue or extreme contrast. More complex illusions occur because an image is misinterpreted. The current thinking among vision scientists is that all illusions are caused by a disturbance to the flow of information between the eyes and the brain. Color illusions occur when colors that have specific relationships are arranged in ways that mislead the eyes.

- An illustration of depth on a two-dimensional surface is not an illusion. An impression of depth in a drawing is created by conventions called pictorial depth cues: shading, shadow, linear perspective, overlap, texture gradient, and atmospheric perspective. Atmospheric perspective is the only pictorial depth cue that has a hue component. Distant objects appear grayer and slightly bluer than closer ones.

- Motion parallax is a depth cue that includes motion and time. When a viewer is in rapid motion, near objects appear to move by in a blur while far objects seem to move slowly. Motion graphics are drawings that include pictorial depth cues, motion, and time. Motion graphics can be true illusions. The most effective illusions of depth result when a full array of depth cues is reinforced by the spatial effects of colors.

- Certain hues suggest transparency. Cool hues often seem transparent. Warm colors containing red seem more dense and opaque. Some colors have spatial effects; inherent qualities of "nearness" or "farness." Light blues seem to move away and warmer and darker colors close in. Dark or light color also influences how the size of a figure is perceived. In general, color is a secondary indicator that supports one or more of the pictorial depth cues. Spatial effects of colors can be reduced or reversed by pictorial depth cues.

- In color compositions the hue, value, and saturation of each form in relation to its ground and to other colors present determine whether it is perceived as advancing or receding. In general, warm hues advance relative to cooler ones. Saturated colors and strong tints appear to come forward relative to muted ones.

- A dark figure will come forward on a light ground and a light figure will come forward on a dark ground. When figures of different value are laid against the same ground, figures with greater value contrast with the ground will advance and those closer in value to the ground will recede.

- A transparence illusion is a three-dimensional illusion that takes place when two opaque colors and an interval between them are arranged in such a way that one color appears to be transparent and lying on top of the other. The guidelines of spatial effects determine which color appears to be on top.

- Fluting is a three-dimensional illusion in which a series of vertical stripes of uniform width appear to have concavity. Vibration is an effect that takes place when blocks of brilliant and complementary (or near-complementary) colors that are close in value are placed together.. Vanishing boundaries occur when areas of similar hue and close value are placed next to or on top of one another. Each form seems to lose its edges and merge into the other.

- Effects of luminosity follow the guidelines of spatial effects. Glowing light is illustrated by setting a light area into a larger and darker field with a "halo" of closely spaced, progressive intervals of value radiating from the light area into the dark. A brilliant hue set into a less chromatic field has the same effect.

- Bezold effect takes place when internal design elements are separated from the ground by dark or light line. When forms are enclosed by dark line, all colors appear darker. When the forms are enclosed by light line, all colors appear lighter.

- An optical mix, or partitive color, is created when two or more colors, in tiny masses or patches just at the threshold of vision, are used together to create a wholly new color.

7

Color Theory: A Brief History

Setting the Stage / The Beginnings of Color Theory / Color and Controversy / The Scientific Model: Color Gets Organized / Color by Numbers / A New Perspective

The starting point is the study of color and its effects on men.
—Wassily Kandinsky Concerning the Spiritual in Art, 1912

Questions and ideas about color—what it is, what it means, how best to organize and display it, and especially, what makes color combinations harmonious—have a long history. The search for answers to these and other questions have produced an enormous library of writing known as *color theory.* Included within it are color-classification and color-order systems; color dictionaries, atlases, and encyclopedias; color as science, color as language, color as poetry, color as art. With the exception of the very earliest writers, there are underlying observations about color that are common to all. When these observations are distilled from the multitude of sources, color becomes a manageable field of study and guidelines—not laws—for achieving color harmony emerge that are consistent, easy to understand, and easy to apply.

Setting the Stage

The earliest known writers on color were Greek philosophers. Intrigued by the elusive nature of color, they sought to establish its place and meaning in the larger universe. To the ancient Greeks, beauty and harmony were aspects of mathematics. The Greek ideal—that beauty and harmony are the natural result of mathematical order, and are inextricable from each other—is a premise that is still firmly in place. Beauty and mathematics conjoined have remained a basis for theories of color harmony from the earliest writings to the present.

Pythagorus (c. 569–490 BC) is credited with originating the concept of the "harmony of the spheres" a mathematical theory in which the planets are separated from each other by intervals corresponding to the harmonic lengths of strings, and therefore give rise to a beautiful musical sound. This ideal was extended to include forms and colors corresponding to the musical scale. Intended in its time to demonstrate the all-inclusiveness of the universe and an overriding wholeness in nature, this proposition still resonates today.

Aristotle (c. 384–322 BC) the most influential of the earliest writers on color, addressed it from both philosophic and scientific standpoints. Aristotle's premise that all colors derive from black and white, or darkness and light, was accepted as fact until well into the eighteenth century.

Renaissance writers, including Leonardo da Vinci (1452–1519) and others before and after him, wrote on aspects of color that ranged from the practicalities of mixing pigments to the philosophical and moral meanings of colors. But writers on color were few, and color remained a topic of narrow and specialized interest until the eighteenth century, when, as the result of experiments by Isaac Newton, it was swept into the mainstream of philosophic and scientific thought.

The Beginnings of Color Theory

During the eighteenth century in Europe, an historical period known as the Enlightenment (or Age of Reason), there was a fresh and vigorous search for rational, rather than mystical, explanations for all kinds of natural phenomena. People began to believe in the existence of irrefutable laws of nature. There was an assumption that there were natural laws for everything, including laws for combining colors, and that these laws, like laws of gravity, only awaited discovery. This search for absolutes determined by science was as rigid and uncompromising in its way as the demands of absolute faith that preceded it. Only the source of authority had changed, from God and his earthly representatives, the clergy, to reason and its earthly representatives, men.

The intellectual world of the eighteenth century was quite fluid. People didn't think of themselves as writers, biologists, or mathematicians but as "natural philosophers," "theologians," or "geometricians," all with wide-ranging and overlapping areas of interest. Philosophers and literary figures wrote confidently, if with dubious expertise, on all kinds of scientific and philosophical topics. Others, poets poised at the edge of the sciences, sought a rational basis for the nature of beauty itself and, as a corollary, color. In this way the "behavior" of colors could be explained and predicted, and the mystery of observed color phenomena mastered through an understanding of natural laws. The search for laws of color harmony was only one small part of the sweeping intellectual ferment of the time.

Two themes dominated eighteenth-, nineteenth-, and early twentieth-century color study. The first was the search for a comprehensive color-order system, including an appropriate format for visualizing it. Once in place, a color-order system could become a field in which the all-important search for laws of color harmony could take place. These treatises, dating from the late eighteenth century and continuing today, make up the collective body of knowledge known as *color theory*. Just as there are classics in literature, there are classics of color study. Two towering and very different figures dominate the beginnings of this discipline: Isaac Newton (1642–1727) and Johann Wolfgang von Goethe (1749–1832). Their observations are the foundations of modern color theory.

Isaac Newton, working at Cambridge in the late 1690s, first split sunlight into its component wavelengths by passing it through a prism. Newton observed that as each wavelength enters a prism it bends, or *refracts.* Because glass, the material of the prism, slows each wavelength down at a slightly different rate, each emerges as a separate beam of light: a distinctly different color. A rainbow is a naturally occurring demonstration of Newton's experiment. Droplets of water in the atmosphere act as tiny prisms, and sunlight is broken into visible colors.

Newton recombined the separated beams with a lens and reconstituted white light. From this he hypothesized the nature of light and the origins of perceived color. He published his results, entitled *Opticks,* in 1703. Newton's conclusion that light alone generates color remains a basis of modern physics.

When Newton observed that white light split in a prism yielded separate colors, he identified

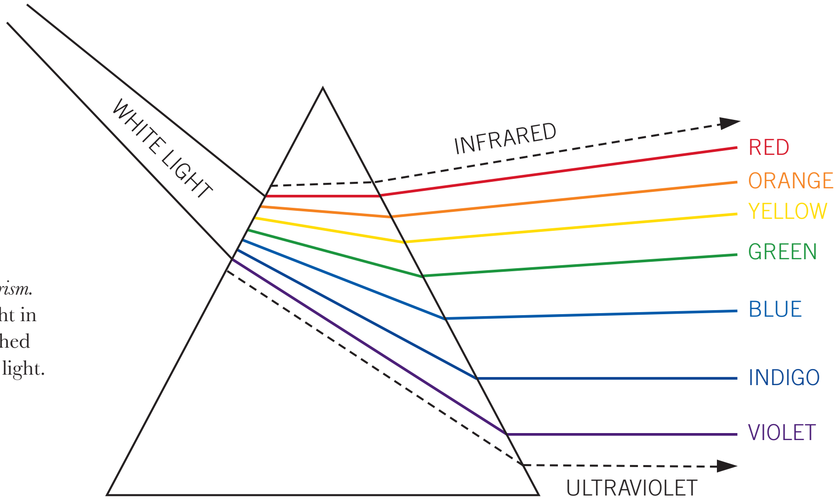


Figure 7-1. *Newton's Prism.* Newton split white light in a prism and distinguished seven colors of visible light.

seven spectral hues: red, orange, yellow, green, blue, indigo (blue-violet), and violet. Many people cannot detect indigo as a separate color of light between blue and violet. There are a number of possible explanations for Newton's choice of seven hues for the spectrum of light. Despite his genius, Newton was a product of the seventeenth century. He may have elected to include seven colors because that number corresponded to the musical notes of the diatonic scale. Mysticism was also a great part of Newton's time, and mystical properties were associated with the number seven. Perhaps he had unusual visual acuity in the blue-violet range. Whatever the reason or reasons, the seven hues of Newton's spectrum remain the standard of physical science in ongoing recognition of his discovery.

Although the spectrum of light is linear, Newton also originated the concept of colors as a *continuous* experience. He diagramed the seven hues as a circle, linking spectral red and violet. This first known illustration of colors as a closed circle made of arcs of individual color appeared in *Opticks.*

Newton's contemporaries viewed *Opticks* as a work on the nature of color, not on the nature of light. By the time of his death in 1727, interest in *Opticks* was widespread. The ideas in it generated tremendous controversy all over Europe.

During this same period artists and artisans were considering color from a wholly different direction. They were not concerned with the study of color as an abstract idea or visual experience. Instead, they sought to resolve the difficulties found in mixing two or more colored *substances* together to achieve a new (and predictable) color. Jacques Christophe LeBlon (1667–1741), a French printmaker, identified the primary nature of red, yellow, and blue while mixing pigments for printing. LeBlon's treatise, *Coloritto* (c. 1730) offers the first concept of three subtractive primary colors.[1] His work attracted a great deal of attention and acceptance. Unlike Newton's earlier theories, which addressed colors of light, and Goethe's later ones, which included ideas about perception and aesthetics, LeBlon's efforts and observations deal with practical realities. His work remains a foundation of present-day printing.

Moses Harris (1731–1785), an English engraver, used LeBlon's three primaries to produce the first known printed color circle (c. 1766). Harris, also addressing subtractive (artists' and printers') colors, was the first to publish them as an expanded circle of relationships—a true visualization of color organization. Harris believed that red, yellow, and blue were the most different from each other and should be placed at the greatest possible distances apart on the circle. To accomplish this he discarded Newton's indigo and created an expanded color circle based on equal intervals of color and multiples of three. This organization was later adopted by the man who is arguably the preeminent color theorist of the late eighteenth and early nineteenth centuries: Johann Wolfgang von Goethe.

Color and Controversy

Goethe was fascinated by color. He was familiar with Newton's theories of color but strongly opposed them, and bitterly resented the acceptance of Newton's ideas. He wrote, furiously, of Newton: "A great mathematician was possessed with an entirely false notion on the physical origin of color, yet, owing to his great authority as a geometer, the mistakes which he committed as an experimentalist long became sanctioned in the eyes of a world ever fettered in prejudices."[2]

Goethe spent a great deal of energy trying to prove that Newton was wrong, publishing his first treatise (of a lifelong series intended to refute Newton's hypotheses) in *Announcement for a Thesis in Color* in 1791.[3] Goethe viewed colors not as light, but as an entity of their own, as *experienced reality*. His difficulties with Newton's ideas are evident in his own words. Newton's theory, he says, "does not help us to perceive more vividly the world around us," so that "even if we found a basic phenomenon, even then, the problem remains that we would not want to accept it as such," and, "Things which belong together according to our senses often lose their connections once we look into their causes." He scolded Newton sharply for his views: "The natural philosopher should leave the elementary phenomena in their eternal quietness and pomp."[4] Goethe's response to Newton is pragmatic. He is really saying, "What you say may or may not be true, but it is not useful in real life."

Like Newton, Goethe was both a genius and a child of the Enlightenment. Unlike Newton, however, he wrote with a sort of shotgun approach, aiming his considerable intellect at a topic, letting fly a lot of ideas, then turning without pause to fire again in a different direction. For today's readers Goethe's writing includes a lot of unintended humor, like discussion of the color sensibilities of earthworms and butterflies. Associations of color and beauty with morality were also a part of Goethe's treatises. There were sinful colors and chaste ones. "People of refinement have a disinclination to colors," declares Goethe, firmly—a bias that will appear repeatedly in the writings of later color theorists. He associated moral character not only with the choice of colors in clothing, but with skin color as well.[5]

Despite his freewheeling digressions, Goethe's observations were wide-ranging and seminal. He and his contemporary Otto Philip Runge (1770–1840), a German painter, shared in conceptualizing what are now called complementary colors. He called them, with enormous insight, "completing colors."[6] Goethe also reported extensively on the phenomena of simultaneous contrast and afterimage. He recognized that no pure color exists except in theory, and characterized the principal contrasts of color as polarity (contrast or opposition) and gradation (intervals). Although other artists and writers expanded Goethe's ideas and added new material, Goethe's observations were so wide-ranging and fundamental that almost every concept in modern color study can be found in his writing.

Goethe's most familiar contribution to color study is the six-hue color circle. Although Goethe believed that there were only two primary colors, blue and yellow, and that all colors derived from them, LeBlon's red-yellow-blue primary color basis prevailed, and the completed Goethe color circle reflects that convention. We know it today as the basic artists' spectrum: equal arcs of six colors: red, orange, yellow, green, blue, and violet. Its elegant simplicity can be described as perfect visual logic.

Goethe's French contemporary Michel Eugene Chevreul (1786–1889), like Le Blon before him, addressed color from a practical viewpoint. As Master of the Gobelin Tapestry Works, Chevreul found difficulties with black dyes, which seemed to lose their depth or darkness when placed next to other colors. Chevreul accepted the three-primary-color theory. He observed and reported at length the phenomenon of simultaneous contrast, and his 1839 treatise *The Principles of Harmony and Contrast of Colors and Their Applications to the Arts (De La Loi du Contraste Simultane des Coleurs)* was a profound influence on the Impressionist movement in painting.

Goethe's six-hue spectrum of subtractive color remains the convention for artists; Newton's seven-hue model of the hues of visible light remains the scientist's spectrum. The battle between Newton and Goethe's color theories was a major schism in the history of ideas. It was unnecessary. Both theories are valid, but each describes a different reality:

Newton was looking at causes.
Goethe was looking at effects.

Probably because students who engage in the sciences are not usually the same ones who pursue the visual arts, the differences between the two ideas about color have, in the past, rarely come into conflict. Designers, like Goethe, work with color from the evidence of their senses. They deal with effects, not causes, and science traditionally has taken a back seat in the studio workplace. The advent of computer-generated design has changed the game. Designers today must understand both cause and effect and be able to work within—and between—both realities.

The Scientific Model: Color Gets Organized

Chevreul and Goethe were gifted observers and obsessive chroniclers. Most of the late nineteenth- and early twentieth-century color theorists who followed them worked instead from a scientific model, codifying their observations into rigidly formal systems. These theorists wrote on color as a discipline, as fact, as scientific truth. The stress was on rules, control, and order; the goal was to create a comprehensive color-order system and to find within it immutable laws of color harmony.

The earliest color-order systems displayed colors as two-dimensional charts: rectangular, triangular, and circular. The concept of color as three-dimensional model, conceptualized by earlier writers, was brought into widely-circulated realization by American Albert Munsell (1858–1918). In *A Grammar of Colors*, first published in 1921, Munsell proposed a "color tree" with infinite room for expansion. Munsell color space is constructed as progessive intervals of hue that rotate around a vertical axis of value from black to white. In Munsell's theory every possible color cannot be shown, but each has an assigned place on an alphanumeric (letter and number) scale. Munsell stated, "Naturally, every point (of color) has a defined number," so that "there can be no new color discovered for which a place and a symbol is not waiting."[7]

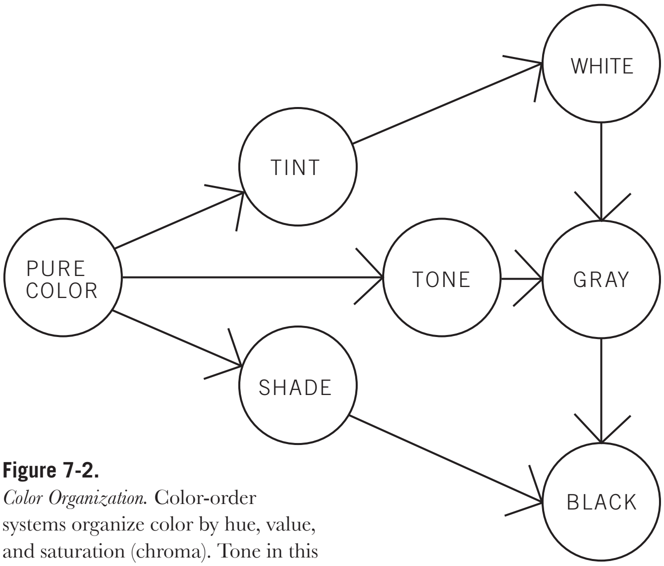


Figure 7-2.
Color Organization. Color-order systems organize color by hue, value, and saturation (chroma). Tone in this illustration represents grayness.

A saturated hue can be reduced in saturation in one of two ways. It can be diluted by the addition of achromatic gray, or by the addition of its complement. Each saturated hue at the perimeter of a Munsell color tree is diluted by a pure gray of equal value. Each hue moves in intervals of diminishing chroma toward the center axis until it arrives at an equal-value gray. Hue intensity is reduced at each step, but value remains uniform along each horizontal branch.

By contrast, complementary colors that dilute one another change in *both* saturation and value at each step as they move toward each other. Instead of reaching an achromatic gray where they meet, each pair of opposites arrives at a chromatic neutral that is visually logical for that pair alone. The complete series of intervals between the two reads as a natural progression. In the Munsell system each hue is placed opposite its complement,

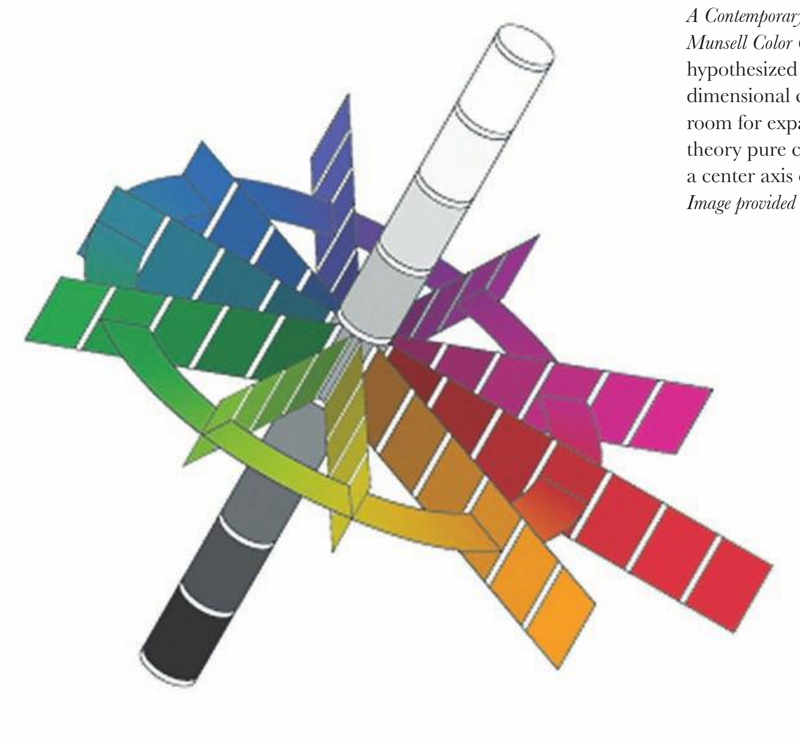


Figure 7-3.
A Contemporary Visualization of Munsell Color Order. Albert Munsell hypothesized color as a three-dimensional construct with infinite room for expansion. In Munsell's theory pure colors move toward a center axis of achromatic gray. *Image provided courtesy of X-Rite.*

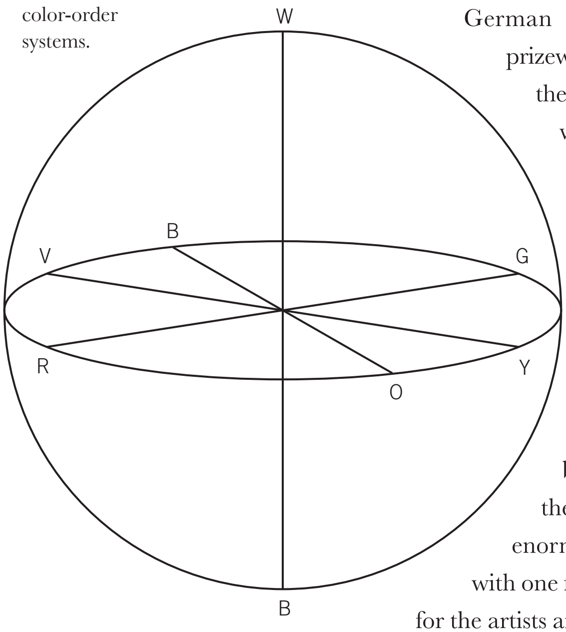
but is independent of it. The entire range of muted hues that is created by the mixture of complements is absent. Munsell might have shown color space as *two* trees—a second one moving toward a center axis of tertiary colors in corresponding value intervals—and come closer to a comprehensive visualization of color space.

Color numbering systems have great value when they are used to communicate color information between individuals who have reference to the same set of standards. Equally useful for additive or subtractive colors, they are essential for specifying color mixes in

Web design, or charts for paints, inks, or countless other products. But color numbering is meaningless as an aid to *understanding* color. Letters, numbers, and formulae for colors are essential production aids that follow the creative process.

Like many early color theorists, Munsell's original work contains distracting associations of colors and morals. Following Goethe, Munsell associated color choices with character and morality, declaring that, "Quiet color is a mark of good taste," and, "If we wish our children to become well-bred, is it logical to begin by encouraging barbarous (i.e., colorful) tastes?"[8] Today, the Munsell system is widely used in industry and in classrooms, but without much of the original commentary.

Figure 7-4.
Color as Three Dimensions.
A hypothetical color solid is a frequent theme in scholarly color-order systems.



German chemist Wilhelm Ostwald (1853–1932), a Nobel prizewinner, brought the conceptual color solid to full-blown theory in *Color Science*. Ostwald's later *The Color Primer*, with its eight-hue spectrum, became mandatory for color study in German schools and in many English ones. It was a strong influence on artists of the Bauhaus movement.

Wilhelm von Bezold (1837–1907) and Ludwig Von Helmholtz (1821–1894) contributed scientific fact to the growing body of color writing. The psychology and physiology of color vision, even color healing, became areas of increasing interest to scientists. By the early twentieth century, color study had become an enormous and wide-ranging topic, positioned uncomfortably with one foot in the sciences and the other in the arts. It remained for the artists and designers of the Bauhaus, a design group founded in 1919 by German architect Walter Gropius, to end its ambiguity.

The Bauhaus group brought the study of color to a level of attention not seen since Goethe's challenge to Newton. Feininger, Klee, Kandinsky, Itten, Albers, and Schlemmer, master-students of color and color theory, approached color from new directions with intelligence, wit, and energy.

Although inevitably some elements of the older, quasi-scientific style encroached on their writing, they made the definitive break between the study of color as science and the study of color as art and aesthetics. Light remained in the realm of physics; chemistry and engineering took over the nature of colorants; and psychology, physiology, and medicine became the arena for perception. Johannes Itten (1888–1967) followed Goethe in exploring color as a series of contrast systems and opposing forces. He theorized seven contrasts of color based on perception alone: contrast of hue, value, saturation, warmth and coolness, complementary contrast, simultaneous contrast, and contrast of extension (area). Itten codified color harmonies as a series of chords based on the complementary relationship and diagramed them as geometric forms (*see* Figure 7-7), and although these chords are mathematically based, Itten's approach to color theory is notably less rigid than many that preceded it. Itten's focus was as much on individual perception as on mathematical relationships. Significantly, his major work is titled The *Art* of Color.

Color by Numbers

Color-order systems were the first concern of theorists because a formal system establishes a structured field in which to search for laws of color harmony. The primary focus of that search was on the relationship between hues, with value and saturation as secondary factors only lightly touched on. Each writer who sought laws of harmony concluded, in one way or another, that the basis of color harmony is order, and more specifically, that harmony lies in a balanced relationship between complementary hues. Goethe repeatedly characterizes color harmony as balance. Johannes Itten says "The concept of color harmony should be removed from the realm of subjective attitude into that of objective principle"[9]; Ostwald referred to "This basic law—Harmony = Order."[10] With his structured charts, Munsell could conclude, "What we call harmonious color is really balance."[11] There was a complete concurrence of opinion: balance between complementary colors was the first principle of color harmony.

The ancient ideal of mathematical balance was so much a part of the search for laws of harmony that hues were frequently associated with numbers or geometric forms. Two examples are representative of the mathematical-balance theories of harmony based on the complementary relationship. Schopenhauer theorized that equal light-reflectance

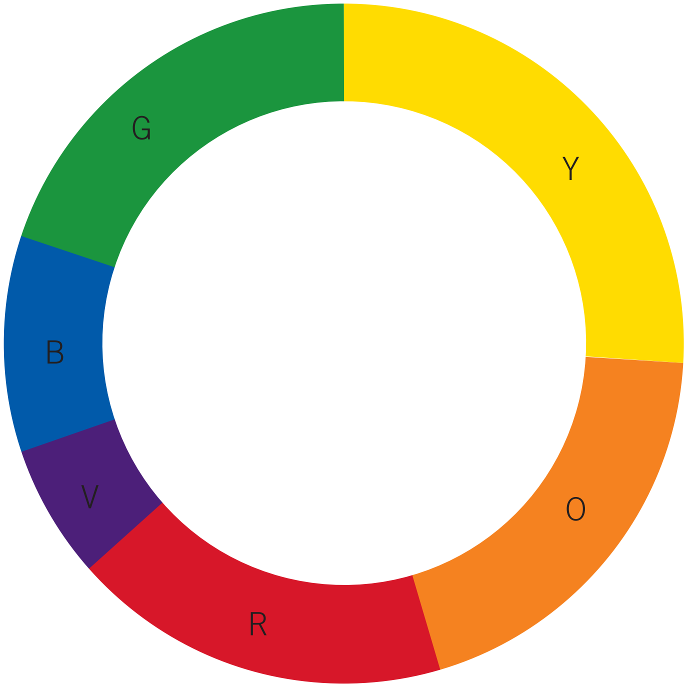


Figure 7-5. *Schopenhauer's Circle of Color Harmony.* Schopenhauer's harmonious color circle is made up of unequal arcs. Each complementary pair is meant to be equal in light-reflectance to each of the other two pairs.

in spectrum colors is inherently harmonious. Using Goethe's color circle as a basis, he suggested a scale of luminosity for each of the six pure hues. Each color is assigned a number representing its light-reflectance (or value) in relation to the others. Yellow, the most luminous, is assigned 9, the highest number. Violet, the darkest of the pure colors, is assigned 3. Red and green are equal in value, and blue and orange are placed relative to the others.

Red	Orange	Yellow	Green	Blue	Violet
6	8	9	6	4	3

The total of all of the numbers added together is 36, or 360 degrees: a full circle. When each pair of complements is added, the total is 12, or a 120° arc on a circle. Each pair of complementary colors thus occupies one-third of the color circle: a perfect mathematical balance of all colors.

red + green:	6 + 6 = 12
blue + orange:	4 + 8 = 12
yellow + violet:	9 + 3 = 12
	36

While this color circle recognizes the disparities in value between the saturated colors, the conclusion it draws is deceptive. A patch of saturated violet that is three times the area of a patch of yellow does not necessarily reflect the same amount of light as the yellow. The light-reflectance of colors is not a function of their area. What it does illustrate, very effectively, is the way we *sense* value differences between pure colors.

Schopenhauer's theory can be illustrated as striped tee shirts. In order for each shirt to be harmonious, the red and green one must have equal-width stripes, the violet and yellow one must have violet stripes three times as wide as the yellow, and the blue and orange must have blue stripes twice as wide as the orange.[*]

Figure 7-6. *Harmonious Tee Shirts (according to Schopenhauer).*

Johannes Itten superimposed geometric forms (squares, rectangles, triangles, and hexagons) over the artists' spectrum to demonstrate what he called "harmonious chords," calling them,

[*] On page 59 of *The Art of Color* (1961) and again in *The Elements of Color* (1970), Johannes Itten credits Goethe with this number series for light-reflectance in pure colors. This material does not appear in Goethe's *Color Theory* (1971), and Albers credits Schopenhauer with the creation of this theory, even referring to Goethe's "dismay" at the tampering with his color circle (Albers 1963, page 43). It's likely that Albers made the correct attribution.

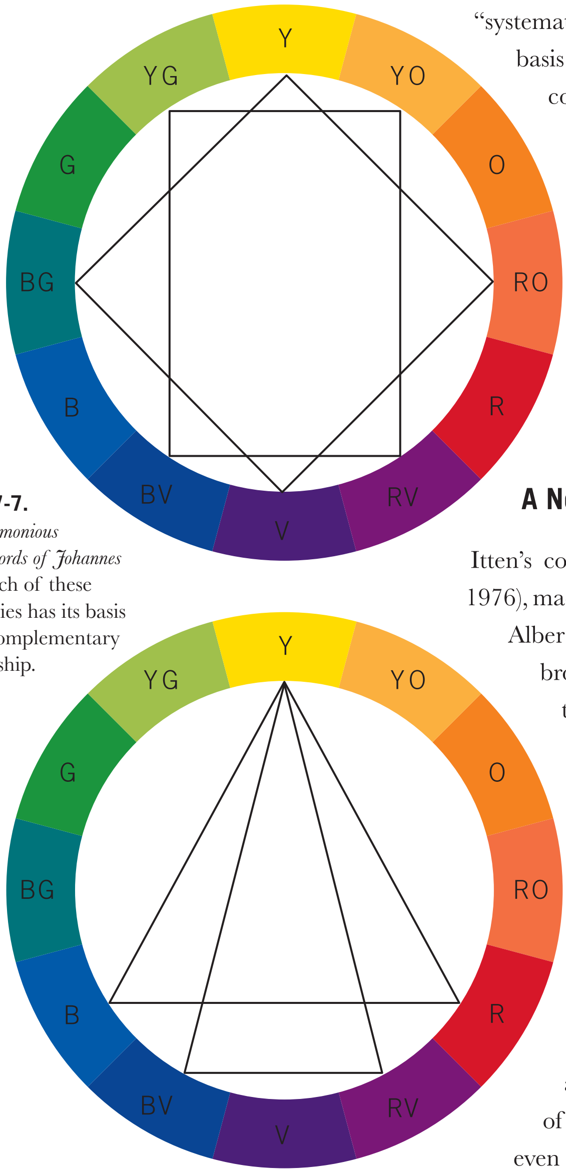


Figure 7-7. *The Harmonious Color Chords of Johannes Itten.* Each of these harmonies has its basis in the complementary relationship.

"systematic color relationships capable of serving as a basis for composition."[12] Each color chord illustrates complementary colors in some measurable proportion. The chords are described as dyads, triads, tetrads, and hexads, with the geometric points locating the "notes" of each chord. The rectangular and hexagonal constructs, called *split complements,* include intermediate colors; but *no chord strays from the complementary relationship*. Each is a variant of the same idea: the harmony of three primary colors presented as opposites.

A New Perspective

Itten's colleague at the Bauhaus, Josef Albers (1888–1976), made the final break with the color-order tradition. Albers fled Nazi Germany in the early 1930s and brought his teaching methods to Yale. He became the most influential name in color theory in the United States, but his 1963 book *Interaction of Colors* contained nothing like the usual charts or systems. Albers did not contribute to ideas of color order. He had a new role to play.

Josef Albers taught that true understanding of color comes from an intuitive approach to studio exercises. He stressed the instability and relativity of perceived colors and the power of visual training. At the same time, he taught that even within this unstable field, there are effects that can be predicted and controlled. In *Interaction of Colors* (1963), Albers casually discounts the generations of theory that preceded him: "This book ... reverses this order and places practice before theory, which is, after all, the conclusion of practice."[13] Albers was not the first to recognize that the visual experience, more than conscious choice, determines how we perceive colors, but he was the first to assert the primacy of the visual experience over structure or intellectual considerations. For Albers, the visual experience, not theory, was paramount.

The late twentieth century saw the focus of color study move from philosophical inquiry to a greater interest in psychological and motivational effects of colors. There is an entire industry, for example, that is devoted to determining current and future consumer preferences in colors and color combinations. At the same time, color theorists continue to search for absolutes. There is an enduring assumption — or perhaps, a hope — that those elusive, timeless, and absolute laws for pleasing combinations of colors really do exist and simply await discovery.

Endnotes

1 Birren 1987, page 11 and Hope 1990, page 189.
2 Lecture 1941, page 3.
3 Goethe 1971, page 13.
4 Lecture 1941, pages 4–6.
5 Goethe 1971, pages 250–261.
6 Ibid. page 55.
7 Munsell 1969, page 10.
8 Ibid. page 41.
9 Itten 1969, page 19.
10 Ostwald 1969, page 65.
11 Munsell 1969, page 14.
12 Itten 1961, page 72.
13 Albers 1963, page 2.

Chapter 7 Highlights

- The Greek ideal that beauty and harmony are the natural result of mathematical order is a premise still firmly in place. Aristotle's (c. 384–322 BC) theory that all colors derive from black and white was a theory accepted as fact until well into the eighteenth century. In eighteenth century Europe a belief arose that natural laws for color existed and only awaited discovery. Treatises from that time to the present day make up the body of knowledge known as color theory. Color-order systems were a first concern of theorists because a formal system establishes a structured field in which to search for laws of color harmony.

- Isaac Newton (1642–1727) is the principal figure of early color theory. Newton passed sunlight through a prism so that each wavelength emerged separately, and from this hypothesized the origins of perceived color. His conclusion that light generates color is a basis of modern physics and the seven hues of his spectrum remain the standard of physical science. Newton also originated the concept of colors as a continuous experience. He diagramed the seven hues as a circle, linking spectral red and violet. Newton's contemporaries viewed his writing as a work on the nature of color, not on the nature of light.

- Jacques Christophe LeBlon (1667–1741) identified the primary nature of red, yellow, and blue pigments. Moses Harris (1731–1785) used LeBlon's three primaries to produce the first known printed color circle (c. 1766).

- Johann Wolfgang von Goethe (1749–1832) strongly opposed Newton's ideas and published extensively in an attempt to refute them. Goethe viewed colors not as light but as experienced reality. He and his contemporary Otto Philip Runge (1770–1840) shared in conceptualizing complementary colors. Almost every concept in modern color study can be found in Goethe's writings. His six-hue circle of subtractive color remains the convention for artists.

- Newton was looking at causes; Goethe was looking at effects. Designers today must be able to work with colors both of light and of substance; with additive and subtractive colors.

- Michel Eugene Chevreul (1786–1889) reported at length the phenomenon of simultaneous contrast in his 1839 treatise The Principles of Harmony and Contrast of Colors and Their Applications to the Arts.

- Most nineteenth- and early twentieth-century color theorists codified color observations into formal systems presented as scientific truth. Colors were presented as two-dimensional charts. An earlier concept of color as three-dimensional model was brought into widely-circulated realization by Albert Munsell (1858–1918) in *A Grammar of Colors* (1921). Munsell color space is constructed as intervals of hue rotating around a vertical axis of value from black to white. Every color cannot be shown, but each has an assigned place on an alphanumeric (letter and number) scale. The Munsell system places each hue opposite its complement, but independent of it. The entire range of muted hues that is created by the mixture of complements is absent.

- Wilhelm Ostwald (1853–1932) brought the conceptual color solid to full-blown theory in *Color Science*. His text *The Color Primer* (1923) became mandatory for color study in many European and English schools. Wilhelm von Bezold (1837–1907) and Ludwig Von Helmholtz (1821–1894) contributed scientific fact to the growing body of color writing.

- Color numbering systems are useful for specifying colors in Web design, charts for paints, inks, or other products. Color numbering is meaningless as an aid to understanding color.

- The artists of the Bauhaus, a design group founded in 1919, made the definitive break between the study of color as science and the study of color as art and aesthetics. Johannes Itten (1888–1967) theorized seven contrasts of color based on perception: contrast of hue, value, saturation, warmth and coolness, complementary contrast, simultaneous contrast, and contrast of extension (area).

- Historically, the primary focus of the search for color harmony has been on the relationship between hues. The bases of color harmony have been held to be order and the complementary relationship. Johannes Itten superimposed geometric forms over the artists' spectrum to demonstrate "harmonious chords," each made up of complementary colors in some proportion.

- Josef Albers' (1888–1976) book *Interaction of Colors* (1963) stressed the instability and relativity of perceived colors and the power of visual training.

8 Color Harmony

In Search of Beauty / Intervals and Harmony / Hue and Harmony / Value and Harmony / Saturation and Harmony / Major and Minor Themes / Some Harmonious Conclusions / On Beyond Harmony: Dissonant Colors / High-Impact Color / The X-tra Factor: Surface and Harmony

The enjoyment of colors, individually or in harmony, is experienced by the eye as an organ, and it communicates its pleasure to the rest of the man.

—Johann Wolfgang von Goethe

There is a theory in design that people will respect and care for surroundings and objects that they find beautiful, and will disdain and neglect, even damage, those that are unappealing. On some level, the pursuit of happiness always includes the pursuit of beauty.

In Search of Beauty

Beauty is the quality of an object or experience that gives pleasure to one or more of the senses. A color can be beautiful, or a sound, or a scent. Delight in the presence of beauty is as natural to the human condition as breathing.

Harmony is the happy condition that follows when two or more different things are sensed together as a single, pleasing experience. Harmony is perceived as complete, continuous, and natural. It is intuitive; a feeling that things are just as they should be. In a harmonious situation everything is in balance; everything *belongs*. Happy families live in harmony; barbershop quartets sing in harmony; a hermit lives in harmony with nature. Harmonious experiences are without gaps or surprises.

Color harmony occurs when two or more colors are sensed together as a single, pleasing, collective impression. A single color can be beautiful, but it cannot be harmonious. Harmony requires a *grouping* of elements. A key characteristic of harmonious colorings is that they seem effortless and uncontrived. Each color seems natural in its relationship to the others. No color seems out of place. To paraphrase Goethe, the colors in harmonious compositions seem to "belong together according to our senses."[1]

A color does not have to be pleasing on its own to be used well. It is perfectly possible to dislike certain colors and still use them in harmonious ways. Someone who asserts that a certain color is "awful" is expressing a personal taste, like a preference for vanilla over chocolate, or jazz over opera. No color is inherently "bad." It is the relationship between the colors in a composition to each other that creates color harmony, not the colors themselves.

Johannes Itten defined color harmony simply, as "the joint effect of two or more colors."[2] But harmony, which implies beauty, is only one possible outcome of combining colors. Not all color combinations are intended to be harmonious. Harmony may be more pleasing than chaos, but it is not necessarily more interesting or exciting. A design concept may call for colors that are distinctly *un*beautiful: startling, visually aggressive, even disturbing. Dissonant combinations of color play a significant role in design.

A more comprehensive term for the force of colors used together is *color effects*. Color effects fall into two broad categories. The first is *color harmony*, the traditional idea of beauty or pleasingness in color combinations. The *"pleasing* joint effect of two or more colors" may be a closer definition of color harmony. The second is *visual impact*: the effect of color choices and combinations on the visual force of a design or image.

Successful color combinations are realized in terms of goal. Instead of thinking about combinations as harmonious or dissonant, they can be thought of as successful or unsuccessful. What was the colorist trying to achieve in choosing the colors? To create an image that has shock value, or high visibility, or a suggestion of luxury? To startle, excite, or disturb the viewer? To evoke association with a particular product or idea? *Color effect*s encompasses the central issue of color use:

What makes a group of colors work together to solve the problem at hand?

The old "laws" of harmony may seem antiquated now, but the observations that gave rise to them remain fresh and valid. They are immensely useful as a starting place for achieving color harmony. But no set of "laws" for color harmony is comprehensive, and no single factor determines it. All aspects of a color composition—hue, value, saturation, the spacing of intervals, and completeness—contribute to a harmonious effect. When all are considered, it is possible to generate color harmonies that transcend historical theory, individual taste, current trends, and cultural bias. Harmony can be found within a premise perfectly stated by Josef Albers: "What counts here—first and last—is not so-called knowledge, but vision—seeing."[3]

Intervals and Harmony

Human intelligence has been described as the search for order in all things. Putting things—any sorts of things—into logical order is irresistible. Babies demonstrate this long before speech, when they arrange blocks or toys in size order. Adults control information in exactly the same way, designating small, medium, large; or ascending or descending letters or numbers. Intervals, particularly even intervals, represent a kind of order in perception. Albers's "What counts here—first and last...is seeing" recognizes the natural human inclination to put things in order. Munsell speaks of "smooth sequences"[4] as harmonious. Even intervals make easy work for the eyes and brain. They are visually and intellectually comfortable. They do not challenge or disturb. *A series of visually logical steps between any colors is inherently pleasing.*

Creating intervals between unlikely elements responds to a recurring problem in design: how to achieve a good result when forced to work with colors that seem at first to be hopelessly incompatible. You have inherited Aunt Maude's buttercup yellow loveseat, but it will have to sit on your old dusty rose rug. Introducing colors that are a series of intervals between the two creates a visual bridge; a connectedness that responds to the human need for order. No matter how unlikely a color combination may seem at first, a series of intervals can establish a kind of order that the eye accepts as logical. *Creating a series of intervals between unrelated colors is a principal way in which they can be transformed into a harmonious grouping.*

At times a color composition seems too sparse, or "thin." A limited palette can be enriched by adding intervals between colors, which expands the palette without disturbing the original color concept. If colors are similar in value and an overall effect seems flat, adding steps of *value* (without changing hues) accomplishes this in a second way.

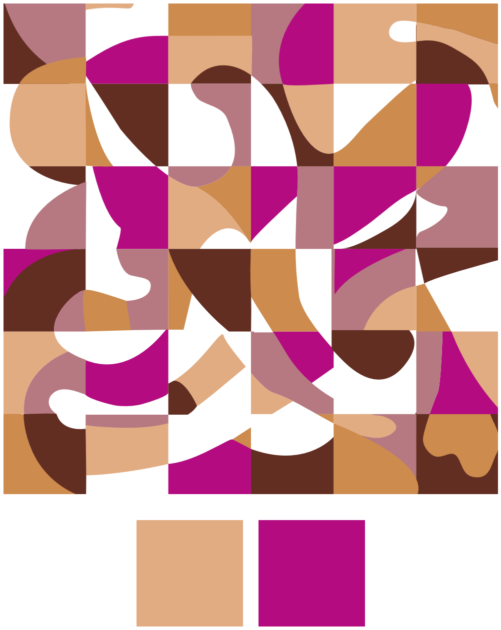


Figure 8-1. *Making it Work.* Creating intervals between two apparently incompatible colors turns them into a pleasing combination.

The *arrangement* of intervals is not necessarily important. That progressive intervals between colors are inherently harmonious is easily observed, but many times a linear progression does not make sense in a composition (*see* Figure 8-3). *Even intervals of any color quality (hue, value, saturation, or any mixture of these) within the same composition tend to be more pleasing than random intervals no matter how they are arranged.*

Hue and Harmony

Historically, the search for color harmony has focused on the relationship between hues, and more specifically, on the link between harmony and complementary colors. Complementary schemes are commonplace in every kind of product from fashion to automotive design. Red (or pink) and green, "peach" (orange) and blue, and "purple" (violet) and "gold' (yellow) are constantly recurring palettes.

Goethe's phrase "completing colors," is a reminder that the eye finds equilibrium in the presence of three primaries. Colors in a complementary relationship are *physiologically* satisfying. The eye is more comfortable at rest than at work, and comfort is pleasing. Albers's "seeing" again goes to the heart of the matter. The complementary-color theories of color harmony are supported by the visual experience at the most fundamental level.

But not every pleasing palette is made up of complements. Colorings are also harmonious when a single hue is used in a variety of values or saturations, as *monochromatic* schemes; or as *analogous* combinations, which contain two primaries but not the third. The menu of possible harmonious hue combinations is a simpler proposition:

Any hues used together can be harmonious.

This does not mean that any hues used together *are* harmonious. It means only that there are no inherently bad hue combinations.

Value and Harmony

Although the principal function of value is as contrast that creates separation between figure and ground, traditional color theory offers three ideas about value and harmony:

Even intervals of value are harmonious
Middle values are harmonious
Equal values in different hues are harmonious

A range of values does not have to extend from the extremes of light to dark to be pleasing, nor does it have to be arranged in a linear progression. Intervals of value will be seen as harmonious as long as steps are equidistantly spaced. When the same image is illustrated using well-spaced steps of value and again with irregular steps, the even-interval version will almost invariably be chosen as preferable. This illustrates one relationship between

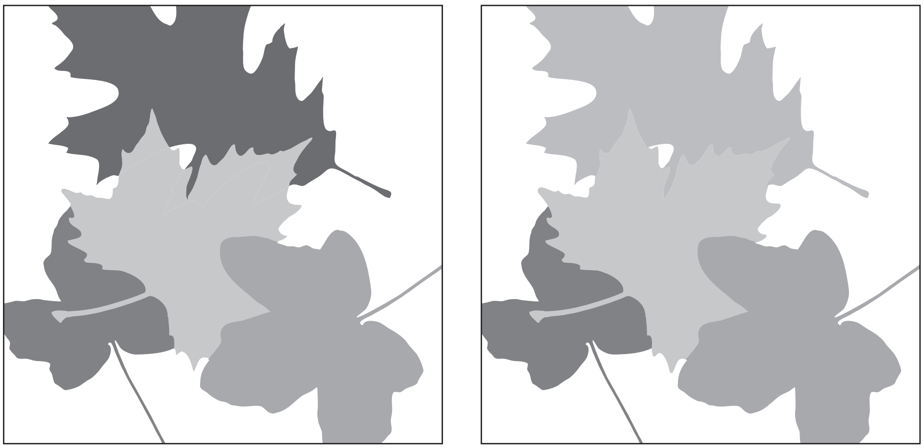


Figure 8-2. *The Harmony of Value in Even Intervals.* Which design is more appealing?

value and harmony and, at the same time, the larger idea that even intervals of any kind contribute to color harmony.

The second premise, that "middle values are harmonious," implies that hues at the extremes of light or dark are unpleasing. To examine this idea, consider first that only the darkest and lightest ends of the value scale are excluded. "Middle values" does not mean only a few samples. There is plenty of light-to-dark range in the middle values.

It is true that middle values are often selected as *preferable* over their much darker or lighter variations. Middle values are easy to see and easy to identify. Any viewer will select first those colors that can be discriminated from others with a minimum of effort. The idea that middle values are inherently harmonious tests the definition of "harmonious" and fails. It is more accurate to say that middle values are often *preferred* than to characterize them as "harmonious." Middle value is not a determinant of color harmony. All values, including extreme darks and lights, are equal in their potential to create harmonious palettes.

The final premise, that "equal values are harmonious," has two distinctly different aspects. Each depends for its success on the intent of the colorist. First, hues of close or equal value can be pleasing *when they are used as carried colors against a contrasting darker or lighter ground.* The image or pattern that emerges from the ground is flattened—it lacks the "forward and back" impression that is associated with the contrast of dark and light—but the presence of many colors offers a different kind of interest and liveliness.

Figure 8-3. *Equal Value Harmony.* Many colors of the same or similar value have a pleasing effect when set against a value-contrasting ground.

Hues of close or equal value also create elegant harmonies *without* a contrasting ground when *no image is intended*. Some of the most beautiful stones, ceramic products, book endpapers, textiles, and wall finishes depend on the interplay of different hues of similar value. Similar-value color harmonies share some of the characteristics of optical mixes, but large areas of color that are close in value do not meld into a single new color. Instead, they create surfaces on which color masses, soft-edged and elusive, float without creating any image or pattern. These richly multihued surfaces can be glorious, whether used alone or as backgrounds for value-contrasting images or patterns laid over them.

Figure 8-4.
Equal Value Harmony. Different hues of close or equal value create rich surface effects. They can be used alone or as backgrounds for value-contrasting patterns.

Saturation and Harmony

Considerations of saturation, or chroma, are an integral part of color-order systems, particularly the three-dimensional constructs. Like any series of steps, intervals between pure hues and their muted versions are pleasing, but the harmony of intervals is only one consideration in the relationship between hue-intensity and harmony. *Color compositions tend to be most successful when the overall level of saturation is relatively constant.*

A relatively constant level of saturation does not mean that all colors are at the same level of brightness. Elaborate compositions like Aubusson carpets have dozens of hues, each in many steps of saturation as well as many steps of value. Complex compositions that include different levels of saturation call for a studied balance between vivid and muted elements. Bright and dull elements are composed together to create a single, cumulative effect that is brighter or more muted.

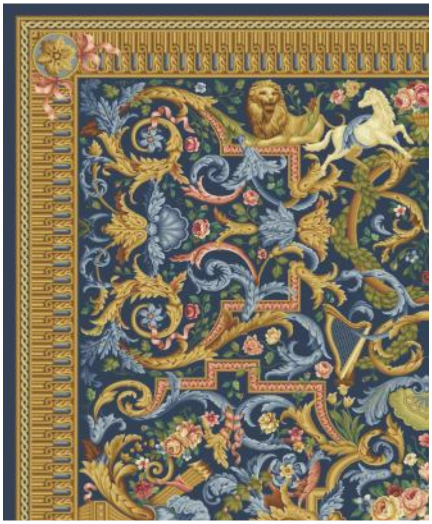
Figure 8-5.
Muted and Bright. A reproduction William Morris wallpaper captures the muted beauty of the original nineteenth-century coloring. *Courtesy of Sanderson*. The contemporary pattern "Primavera" from Clarence House has all the exuberance of saturated color. *Courtesy of Clarence House.*

When a general level of saturation has been established, any atypical element is disruptive. A single pure color inserted into a muted palette will pop forward. A muted color appears grayed or dirty, and recedes when it is included in a composition of brilliant colors. It appears as a blot in the clean brightness around it.

Figure 8-6.
Uniform Saturation. A palette of pale, muted hues creates a soft background for strong black lettering. *Image courtesy of Carin Goldberg Design.*

The role of saturation in color harmony is distinct from its role in illustration. Muting a color in steps, or as a gradient, is a classic means of depicting three dimensions. Progressive intervals of saturation allow brighter colors to come forward gradually, creating a soft impression rather than a sharply graphic one. In a flower-printed textile, for example, movement from bright green to muted gray-green suggests leaves receding into gentle shadow.

Figure 8-7.
Complex Harmony. This modern Savonnerie carpet contains over 60 different colors, but only three hues. *Carpet design by David Setlow. Image courtesy of Stark Carpet.*



It has been argued that muted colors are naturally more harmonious than saturated colors because the eye is at rest in the presence of muted color. This idea, too, fails the definition of harmony. Brilliant colors in combination are exciting and muted ones are calming, but neither is inherently more harmonious than the other. Only the relationship between colors creates color harmony, not the colors themselves. Harmonious compositions are possible with colors at any level of saturation.

Major and Minor Themes

Many complex colorings have an additional characteristic. There is a dominant hue family; most often a group of analogous colors; this principal theme is enlivened by smaller areas of complementary or near-complementary colors. A carpet may have dozens of yarns in the blue-to-green range. Some are brilliant and others muted; some dark, some light. The blue-to-green range is the major theme; the dominant hue family is blue-green. Small areas of the complementary red to red-orange support and reinforce the cool hues, emphasizing the blue-green by contrast and fulfilling the eye's need for equilibrium. Color compositions in which two or more hue families compete for *equal* attention are often less successful than those with major-minor hue relationships.

Some Harmonious Conclusions

A central feature of successful harmonies is completeness. The ground is often the largest single area in a composition, and that idea of completeness includes consideration of the color of the ground, even when it is simply white. White is no more an absolute than any hue. Every white has some undertone: yellow, green, blue, gray, violet, or some other color. Blacks and grays, too, carry undertones. There are green-blacks, blue-blacks, violet ones, brown ones. A well-chosen ground means the difference between a fully realized color harmony and a less satisfying one.

Much of the time colors for objects, print, and screen are chosen either to appeal to, or to attract the attention of, the widest possible audience. Following the guidelines for color harmony does not guarantee that a particular colorway will have universal appeal. There is always an element of personal bias in color preference. But there is no way to escape the conclusion that a great deal of what we find harmonious originates as involuntary responses of the eyes and mind. The brain has a built-in bias for certain kinds of combinations.

It is a little disconcerting to think that preferences in color combinations are predetermined by physiology and the unconscious, but that is only one part of the story. An impression of harmony is influenced by the eye's need for equilibrium, the comfort level of vision, the human need for logic in perception, and finally, by each individual's emotional response.

An instinct for what is harmonious can be trusted because the eyes dictate boundaries of comfort. We enjoy the accidental beauties of nature. In design, harmonious colorings are not accidental. They are deliberate. The designer's mind, hand, and eye creates each new palette, and the designer's *intent* determines whether that palette is harmonious—or otherwise.

It is good practice to avoid a reverence for authority when searching for color harmonies. The traditional principles have validity, but they are limited in scope. "Laws" of harmony are stifling to the creative spirit. No new idea ever grew from a strict adherence to rules.

What does make sense is to consider some observations about color harmony:

- No single factor determines color harmony.
- The complementary relationship between hues is a strong basis for harmony, but it is not the only basis. Any hues used together can be harmonious.
- Even intervals between colors contribute to harmony. Even intervals are pleasing whether they exist between hue, value, saturation, or any combination of these.
- Color compositions tend to be harmonious when the level of saturation is relatively constant.
- Compositions of many colors tend to be most successful when a dominant family of analogous hues is supported by smaller areas of their complements.

On Beyond Harmony: Dissonant Colors

If color harmony is the good child of design, its polar opposite is disharmony, or dissonance. Dissonant colorways are disturbing. Colors do not seem to belong with each other. If harmony conveys balance and order, disharmony communicates imbalance, unease, edginess, chaos; a sense of things missing or "off-kilter."

Dissonant colorings can be dynamic and exciting—not pleasing perhaps, but certainly a way to draw attention. When the guidelines of color harmony are deliberately ignored, the result may startle or repel, but it may also be memorable. Unpleasing colorways have their own strengths.

Figure 8-8. *Dissonant Color.* Dissonant color combinations have their own place in design. The coloring of this early-twentieth century textile was stylish in its time. "Stylish," however, does not necessarily mean "harmonious."

High-Impact Color

Some design problems call for colors or combinations that will draw instant attention. The strongest images are created by high value contrast alone, a graphic power that requires no hue. The addition (*not* the substitution) of brilliant color to an already powerful image does not change the strength of the image. Instead, it affects the amount of *time* it takes to capture the viewer's attention. Colors that are both hue-intense and light-reflecting, like a strong tint of red-violet, or a saturated yellow-green, have an eye-catching immediacy. Only a few saturated hues are high-impact colors. The range of violets, for example, is not light-reflecting enough to draw immediate attention. When a highly visible violet is called for, a strong tint is used. Working with high-impact colors is not necessarily an alternative to color harmony. Colorings can be both brilliant and harmonious.

Figure 8-9. *High Impact Color.* High-impact colors attract attention more quickly than softer ones.

Brilliant colors used together without some intervening value contrast are likely to vibrate, so although they draw immediate attention, they are poor candidates for good readability. Because these colors often contrast sharply with their surroundings, they are useful in communicating nonverbal warnings. The Occupational Safety and Health Administration (OSHA), for example, uses high-impact colors symbolically to alert for specific dangers—a tint of violet for radiation, vivid orange for hazardous situations.

Fluorescent colors, sometimes called neon, or "DayGlo" colors, are an extreme of high-impact color. They include a colorant that absorbs wavelengths of light from the UV range (non-visible light) of the spectrum and re-emits it as visible light. This added light-reflectance makes the colors extremely brilliant and attention-getting.

High impact color can also be used to *direct* attention. An area of brilliant color set into a more muted palette injects an element of surprise into a composition. It creates a point of focus that draws attention to itself and away from the composition as a whole.

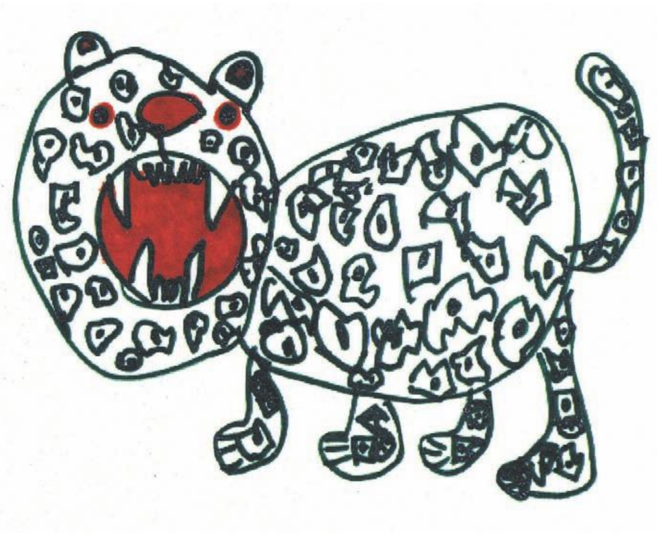


Figure 8-10. *The Element of Surprise.* A patch of unrelated high-impact color draws attention to itself and away from the composition as a whole. *Image courtesy of artist Emily Garner.*

The X-tra Factor: Surface and Harmony

The natural world is a richly chromatic experience. Extraordinary brilliant and subtly muted colors coexist. Rarely is nature truly colorless. The colors of nature are also fragmented. Much of the time they are better described as optical mixes than as flat color.

Broken color, suggesting texture, invites a tactile response as well as a visual one. A textured surface (or the impression of one) engages more of the senses than an area of flat color. Fragmented color responds to the human need for connection to the natural world. One familiar example of broken surface color used to evoke this response exemplifies how human beings respond to it. Many medical facilities hang images of nature in waiting and treatment areas because they are calming to patients and their families. When medical facility art work is nonrepresentational, the colors are soft-edged and irregular, rather than hard-edged and geometric.

Flat color has its own purpose and place in design. Where broken color suggest nature, hard-edged, flat colors are dramatic and compelling. They have a discipline that responds

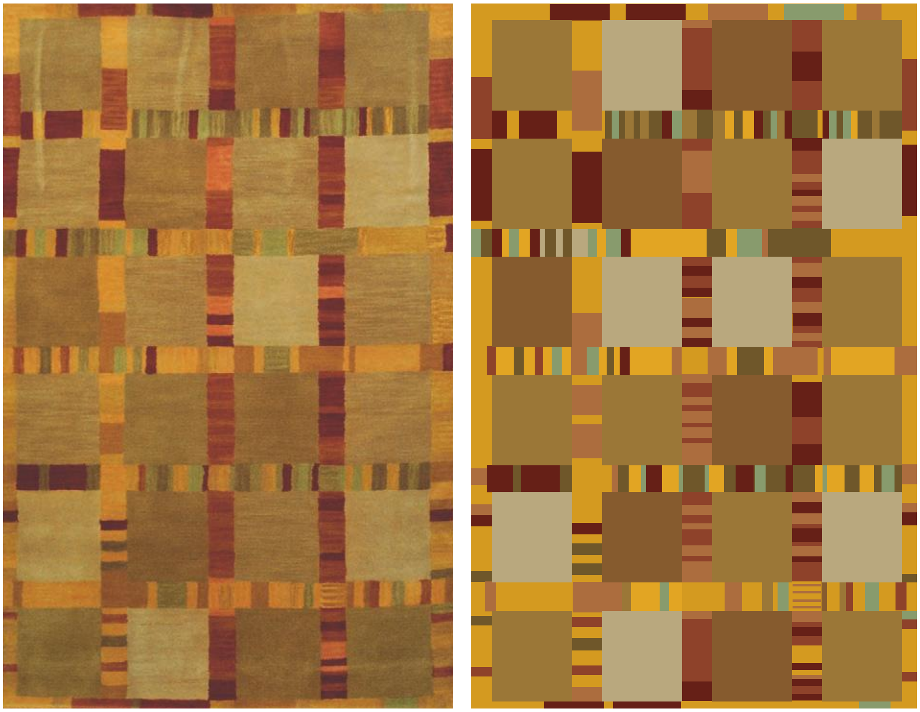


Figure 8-11.
The Appeal of Texture. The irregular colors of hand-dyed yarns give the carpet a warmth and appeal that seem to invite touch. The same pattern created in flat color lacks tactile appeal. *Image courtesy of Safavieh Cosmopolitan Collection CM413A © Safavieh 2005.*

to an entirely different human need: the need to control. The designer of a new electronic device is unlikely to specify coloring that suggests the texture of autumn leaves. A surface that is flat, sleek, and flawless offers an impression of precision. The decision to use flat or broken color is a small but meaningful side trip on the road to successful color choices.

Endnotes

1 Lecture 1941, pages 4–5.
2 Itten 1961, page 21.
3 Albers 1963, page 2.
4 Munsell 1992, page 36.

Chapter 8 Highlights

- Beauty is the quality of an object or experience that gives pleasure to one or more of the senses. Harmony occurs when two or more things are sensed together as a single, pleasing experience. Color harmony occurs when two or more colors are sensed together as a single, pleasing, collective impression. The relationship between colors in a composition to each other creates color harmony, not the colors themselves. Any colors can be used harmoniously. Not all color combinations are intended to be harmonious. Dissonant combinations of colors can be dynamic and exciting; a way to draw attention

- A comprehensive term for the force of colors used together is *color effects*. All aspects of a color composition, including the ground, contribute to color effects. Color effects fall into two categories. The first is color harmony. No set of "laws" for color harmony is comprehensive and no single factor determines it. The second is visual impact, or the effect of color choices and combinations on the power of an image. Color effects encompasses the central issue of color use: What makes a group of colors work together to solve the problem at hand?

- A series of even intervals between any colors is inherently pleasing. Creating a series of intervals between unrelated colors is a principal way in which they can be transformed into a harmonious grouping. A limited palette can be enriched by adding intervals between colors, which expands the palette without disturbing the original color concept.

- Colors in a complementary relationship are physiologically satisfying. The complementary color theory of color harmony is supported by the visual experience. The complementary relationship between hues is a strong basis for harmony, but it is not the only basis. Any hues used together can be harmonious. Monochromatic and analogous colorings are also harmonious. There are no inherently bad hue combinations.

- Even intervals of any color quality within the same composition tend to be more pleasing than random intervals no matter how they are arranged. All values, including extreme darks and lights, are equal in their potential to create harmonious palettes. Middle values are often preferred because they are easier to discriminate than very light or very dark colors. Preference is unrelated to harmony.

- Hues of close or equal value can be pleasing when used as carried colors against a contrasting darker or lighter ground. Hues of close or equal value also create elegant harmonies without a contrasting ground when no image is intended.

- Color compositions tend to be most successful when the overall level of saturation is relatively constant. Complex compositions that include different levels of saturation call for a studied balance between vivid and muted elements. Harmonious compositions are possible with colors at any level of saturation. The role of saturation in color harmony is distinct from its role in illustration.

- Complex compositions made up of many colors tend to be most successful when there is a dominant family of hues supported by smaller areas of their complements. Color compositions in which two or more hue families compete for equal attention may be less successful than those with major–minor hue relationships.

- Brilliant colors that contrast sharply with their surroundings are useful in communicating nonverbal warnings. The addition of brilliant color to an already powerful image affects the amount of time it takes to capture the viewer's attention.

- Broken color, suggesting texture, invites a tactile response as well as a visual one. Hard-edged flat colors respond to the human need to control.

9 Tools of the Trade

It's the Real Thing: Color in Product and Print / Design Media / Artists' Media / Subtractive Mixing / Tinting Strength / Color Printing

The artist studies his materials and methods in order to gain the greatest possible control over his manipulations, so that he may bring out the best characteristics of his chosen technique, and express or convey his intentions....

—Ralph Mayer

Every manufactured object represents the culmination of a design/build process. Individuals or teams create design prototypes, but the final product—the real thing—is fabricated by others. The creative phase of product development ends at the moment when goods go into production.

Designers use renderings and models to visualize new products and graphics. Ideas for new forms and colors are sketched, modified, revised, and ultimately tweaked into final form for production. The finished illustration has a second and equally important use. Renderings are the means of *selling* design and color. They are the principal way in which new product and color ideas are communicated to potential buyers.

It's the Real Thing: Color in Product and Print

Objects and printed pages can be described in terms of their color qualities, but they are *experienced* in more complicated ways. The full impact of any object's color includes subtleties of texture, light-reflectance, and other, harder-to-define qualities. The blue of a ceramic tile and the blue of a velvet may be described using the same words, but one would never be mistaken for the other. It is difficult for people to think of the color of something as independent of its other attributes. Most of the time, the form, surface, and color of an object are understood as a single experience.

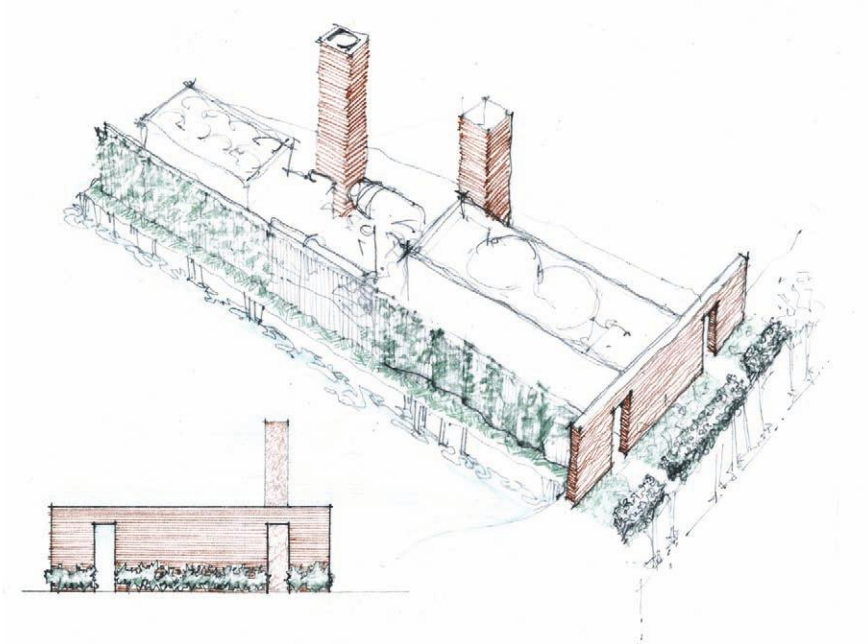


Figure 9-1.
Traditional Rendering: Architect Daniel Brammer's meticulous pencil drawing brings a structure to life on paper. *Image courtesy of Daniel Brammer for Cook+Fox Architects.*

Figure 9-2.
Traditional Rendering. A gouache rendering offers a vibrant image of a proposed new seaside veranda. *Image courtesy of Drake Design Associates.*

A surface scatters general light in a way that is characteristic of a particular thing and others like it. The pebbled yellow surface of a lemon is understood *as* the lemon. A lemon-shaped, lemon-colored form that is smooth and shiny is not identified in the same way. Two images printed on white paper using the same ink will read differently if the underlying paper surfaces are unlike. A matte paper scatters light in many directions; colors printed on it are diffused and softened. The same ink printed onto glossy paper seems sharper and more dramatic. Deep reds and golds printed onto velvet seem soft and lush; the same colors on a glossy vinyl seem sharp and aggressive.

Both natural and man-made materials are used in the manufacture of consumer goods. Natural materials like stone, wood, silk, linen, cotton, and wool have random gradations and shadings that many consumers find appealing as they are, without added color. Natural materials often have color added without losing the attributes that make them appealing in the first place. Wood can be stained to brilliant color without losing visible grain. Cottons, wools, linens, and silks can be dyed to any imaginable color without losing characteristic texture and light reflectance.

Figure 9-3.
Art Imitates Nature. Wilsonart laminates simulate the texture and colors of natural granite. *Image courtesy of ©Wilsonart International, Inc.*

Man-made materials in general need color added to make them attractive to consumers. The added color often simulates a natural material: petroleum- or cellulose-based materials textured and colored to simulate natural wool, linen, silk; wood, and stone are commonplace. Other synthetics may call for high color: a brilliant blue engineered stone, or a bright yellow vinyl floor tile.

Products are colored in three principal ways. Color can be introduced directly into the raw material before the start of the manufacturing process, chemically bonded to the surface of a material, or applied as a coating at a late stage of manufacture. Products are also colored using a combination of these means: a textile can be dyed, for example, then overprinted after dyeing.

Plastics, solid vinyl floorings, engineered stone, and solution-dyed man-made fibers are examples of products whose color is introduced into the base material at the earliest stage of manufacture. In solution dyeing of textiles, for example, the colorant is introduced into a chemical "soup" before it is extruded into fibers. There are limitations to introducing a colorant into any material. The colorant and base material must be chemically compatible, and not all colorants are compatible with all substances. The inclusion of color into the substance of a material offers some advantages: chipping or fading, for example, become lesser problems. But producing a separate base material for each colorway in a product line is costly, so the number of colors available in color-through products is often limited.

Dyes form a chemical bond with the substances to which they are applied. Textiles are the most familiar dyed products. Textiles can be dyed as fluff, before yarn is spun; or dyed as yarn; or piece-dyed after the fabric has been woven. Dyes are also used to introduce color into materials such as wood, paper, leather, fur, and even stone.

Figure 9-4. *Applied Color.* The floral design of this English Ironstone China plate is painted on at a late stage of manufacture.

Finally, color can be applied as a coating to the surface of a product, typically at a late stage of production. Coverage can be complete, like paint or ceramic glaze, or used in partial areas, as in a printed textile. The coating can be opaque, masking the underlying substrate completely, or it can be semi-transparent, allowing some of it to show through. Applied color enables a manufacturer to offer a greater number of color choices because the same underlying material is used for all colorways. Applied colors have their own limitations. They must adhere to the underlying material and perform well in normal use, without chipping, flaking, rubbing off, or bleeding.

Design Media

A *medium* is a means—something through which an idea, or a substance, or an image, is conveyed.[1] A *design medium* is a means of translating images, ideas, and colors from one kind of visual experience to another. A three-dimensional reality (like a person or object) becomes a two-dimensional image through the medium of paint on paper, or light on a screen. A good design medium transmits the force of a whole visual idea. The best design media enable designers to create images that closely approximate the forms, textures, and colors of the end product.

A product moving through design development passes through many stages of visualization. It may begin as a marker sketch or a digital drawing, move into print, be a photograph or data on CD or DVD. It may appear on the Internet or on television, where it will be received by a wide variety of computer and television monitors, each with its own color-rendering qualities.

All fields of design share the same challenge: visual thinking and presentation must take place in (at least) one medium when the color of the actual product is achieved in an altogether different way. Each rendering must approximate as closely as possible not just color, but a sense of the whole product. Two very different kinds of media are used to achieve this goal. One is the traditional paints, inks, and markers of the artist-designer. The other is the near-universal medium of the present-day design studio: the on-screen imagery of digital design.

Artists' Media

Traditional artists' media produce subtractive color. They are substances made up of a liquid, paste, viscous, solid, or other inert base that contains a colorant. The colorant, a dye or pigment, selectively absorbs and reflects wavelengths of light. The base is a vehicle (or means) for transferring the colorant from one thing to another—from brush or pen to paper, for example. The base and colorant together make up the *medium*. In a good-quality artists' medium the colorant permeates the base evenly and transfers smoothly. There are literally hundreds of different subtractive media, among them poster paints, opaque and translucent watercolors, oil paints, acrylic paints, markers, crayons, colored pencils, dyes, and inks.

Dyes are colorants in solution. The colorant is fully dissolved in water, alcohol or some other solvent. Dyes penetrate the material they color and bond with it on the molecular level.

Some dyes are translucent, others are opaque. A translucent dye acts as a filter, allowing light to pass through it and reflect back from a white (or light) surface below. When light reflects from a white fabric back through a dye, or when a translucent ink is laid on a white paper ground, the effect is light-reflective and clear.

Pigments are finely ground particles of colorant suspended in a liquid or other vehicle. Pigments "sit" on a surface rather than bonding with it. They are typically more opaque and less brilliant than dyes. Not all artists' colors fall neatly into a dye or pigment classification. *Lake* colors, for example, are dyes that have been bonded to a finely ground material, usually a white clay, then suspended in a base. They have the brilliance of dyes but perform with the opacity of pigments.

Before the mid-nineteenth century most dyes were organic; derived from plant or animal material. Many were fugitive, oxidizing (fading or changing) rapidly on exposure to light or air. Pigments were made from ground earths; some, like lapis, were ground from semiprecious stones. The inorganic nature of pigments made them more durable than dyes. The accidental discovery in 1856 of coal-tar dyes precipitated a quest for ever more stable and brilliant synthetic colorants. Today's high-performance synthetic colorants have properties and durability unimaginable in the past. Because of their complexity, many of these products bridge the traditional distinctions between dyes and pigments.

Although the colorant alone determines the hue, the base of each medium has a part in overall color impression. A base is inert only in the sense that it does not modify light *selectively.* Dyes and pigments are selective, absorbing some wavelengths and reflecting others. A base modifies color by absorbing, scattering, or reflecting *general* light. Color qualities like translucency, opacity, and chalkiness depend many times on the light-modifying qualities of the base.

Watercolor and crayon are examples of media whose differences come largely from the modifying quality of the base. Water is a colorless substance that transmits light. It evaporates completely after it is applied, leaving the colorant essentially unmodified. A brilliant dye that is dissolved in water and applied to a white substrate (underlying material), renders colors that are light-reflective, clear and brilliant. Crayons carry the colorant in a wax base. The wax is dense, cloudy, somewhat shiny, and slightly translucent. Unlike water, the wax base of a crayon remains after it has been transferred to paper. Wax absorbs a bit of the light reaching it, scatters some light, and allows some light to reach the underlying surface. No matter how brilliant the colorant in a wax crayon, the wax mutes the final color impression to some degree.

Some media have special properties and special uses. "Dayglo" colors, for example, include a substance that absorbs wavelengths of light from above the range of the visible spectrum and re-emits it at a lower range, as visible light. The added light-reflectance makes these colors useful for attention-getting purposes, like safety cones on the highway, because they are highly visible against any background. Metallic media are made up of finely ground particles of copper, zinc, or aluminum in different proportions that mimic the sheen and color of various metals. The particles are suspended in a base, usually a resin, that can be tinted with conventional colorants for further effect. Yellow can be added for gold, or muted orange for copper. The metal particles scatter light in many directions and the resulting colors are light-reflective but diffused, with a soft glow. High-gloss metallics are also available in many media.

Subtractive Mixing

No medium exists as a complete range of visible hues with all tint, shade, and chroma (saturation) variations. Instead, each has a limited number of colors that can be used alone or mixed together to extend its range. A medium may be available in a large number of colors, like oil paints or children's crayons, or have a only few very similar colors, like natural chalks. Different kinds of liquid or paste colors can be mixed together successfully only when the bases are compatible. A water-based acrylic paint, for example, will not mix with an oil-based paint.

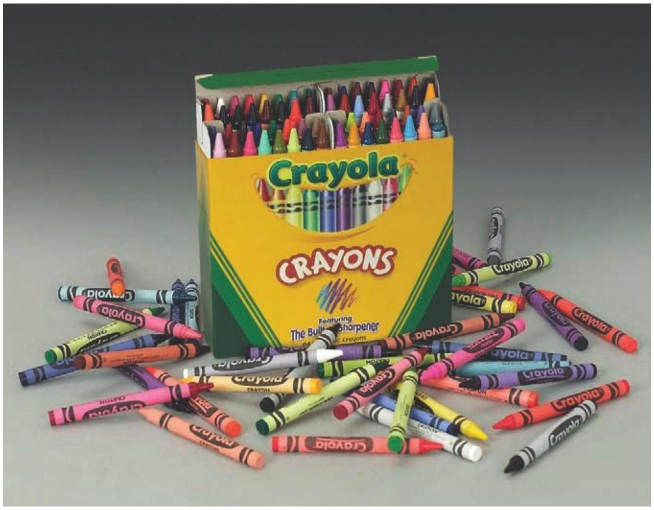


Figure 9-5.
Artists' Media. The multitude of colors available in Crayola crayons has been an early inspiration to generations of artists and designers.

Artists' colors are mixed in a visually logical way. Mixing a new hue follows the sequence of the artists' spectrum: two colors are mixed together to produce the hue that lies between them. But two artists' colors that are mixed to make a third do not *dependably* produce the expected result.

A single medium may have a number of tubes or jars of what seem at first glance to be near-identical colors with different names. These colors share the same base, but each contains a different colorant, and each colorant reacts differently when mixed with others in the same medium. A red chosen at random and mixed with yellow will not necessarily make orange. *In order for two colors to produce a new hue, their colorants must reflect a wavelength in common.*

Most colorants do not reflect a single wavelength. Instead, they reflect light in a range of wavelengths, with one or a few wavelengths typically much stronger than others. The perceived color is the wavelength that is reflected most strongly, while others present may be reflected so weakly that they are not apparent.

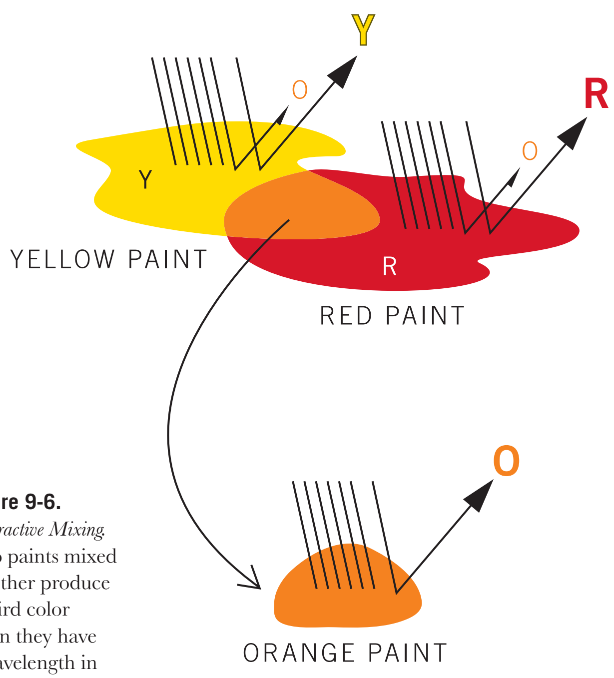


Figure 9-6.
Subtractive Mixing
Two paints mixed together produce a third color when they have a wavelength in common.

A red paint may absorb the yellow, green, blue, indigo, and violet wavelengths. It reflects a strong red wavelength and a weaker orange one. A yellow in the same medium may absorb red, green, blue, indigo, and violet wavelengths. It reflects a strong yellow wavelength and a weaker orange one. When the red and yellow paints are mixed, the mixture of the two absorbs all of the colors that each absorbed when used alone. The red in the new mixture absorbs the yellow wavelength, and the yellow absorbs the red. The only wavelength left to be reflected is orange, the *one wavelength that each of the two reflects in common.*

Paints that do not reflect a common wavelength mix to a kind of mud color. No matter how brilliant a red colorant may be, for example, if that red also reflects violet and is mixed with a yellow that also reflects green, the resulting mixture will be drab. Mixed together, the two absorb all colors of light. Children's poster paints are a classic example of a medium with poor mixing qualities. The primary colors of "kindergarten" grade poster paints do not produce clean secondary colors. Blue and yellow together produce a sickly khaki; red and yellow a brownish orange, and blue and red a sort of purplish dirt color.

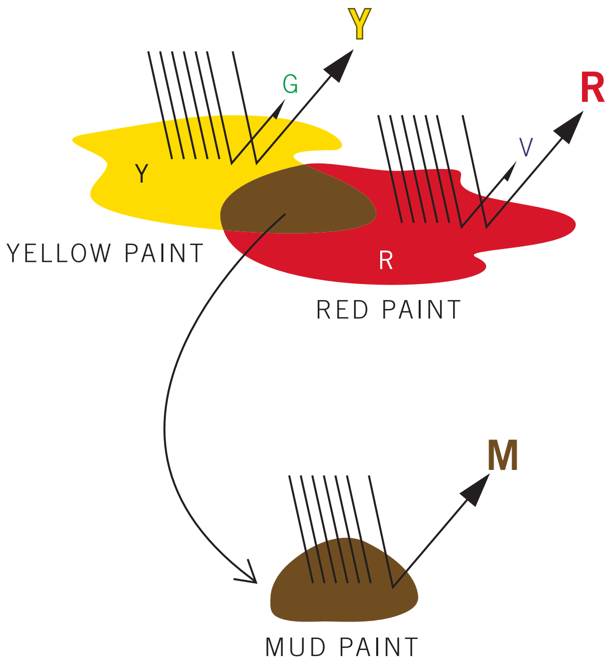


Figure 9-7. *Subtractive Mixing.* Two paints that do not reflect a wavelength in common mix to a muddy neutral.

An experienced colorist mixes new colors based on the mixing affinities of specific tube or jar colors within a medium. The skills of color mixing are not the same as the ability to see differences, similarities, and intervals between colors. Each medium calls for its own set of technical skills, but all media demand the same color discrimination skills.

Tinting Strength

Tinting strength refers to the relative *quantity* of a color needed to produce a perceptible difference when mixed into another color. Different tube or jar colors within the same medium will vary in tinting strength.

When colors are mixed, *quantity* does not necessarily produce a predictable result. Only tinting strength matters. Most yellows, for example, have little tinting strength. Adding one-half cup of yellow paint to one-half cup of green paint causes little change in the green. But a teaspoon of green added to a cup of yellow changes yellow to yellow-green at once. Colorants with great tinting strength are like garlic. A teaspoon of garlic in an apple pie will certainly be noticed. On the other hand, a teaspoon of apple in garlic soup does not make much of an impression.

Color Printing

Process colors are the principal medium of the printing and reprographic industries. The process color primaries are cyan (blue-green), magenta (red-blue), and yellow. Magenta is also called process red; cyan, process blue; and yellow, process yellow.

Figure 9-8.
Process Colors.

Process color, or CMYK (**C**yan, **M**agenta, **Y**ellow, and blac**K**) printing is the most familiar and universally available printing process. It is used in color xerography, computer color printers, and commercial color-press printing. The special colorants used in CMYK printing inks are also available in other media such as drawing inks, films, and markers, which is helpful to designers preparing art for CMYK printing. A design rendered by hand in process-color markers or drawing inks closely approximates the colors of the printed page.

Process colors are categorized as a subtractive medium, but they produce colors in a completely different way from artists' colors. Instead of selectively absorbing and *reflecting* wavelengths of light, process colors act as filters. Each process primary absorbs one wavelength of light and *transmits* the others.

> Process magenta absorbs green and transmits red and blue.
> Process yellow absorbs blue and transmits red and green.
> Process cyan absorbs red and transmits blue and green.

When a process primary is laid on white paper, some wavelengths reaching it are absorbed and others are transmitted to the paper surface below. The white surface reflects the wavelength reaching it back through the ink "filter," and that color reaches the eye.

When process inks are mixed, they continue to absorb and transmit the same wavelengths. The secondary colors that result from mixing process primaries do not correspond to the colors that result from mixing artists' colors *or* the mixing of light.

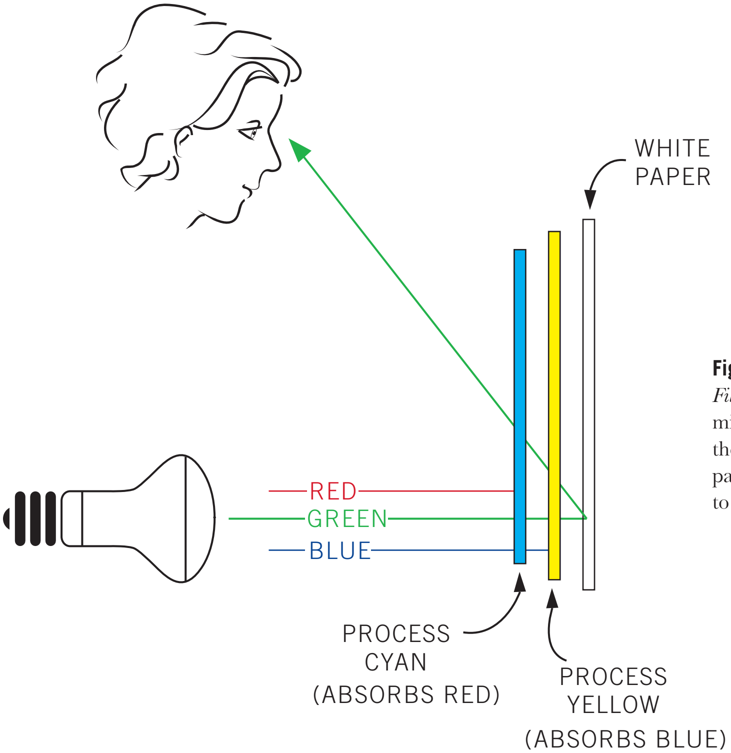


Figure 9-9. *Process Colors Act as Filters.* Here, cyan and yellow mixed absorb red and blue. Only the green wavelength reaches the paper surface and reflects back to the eye.

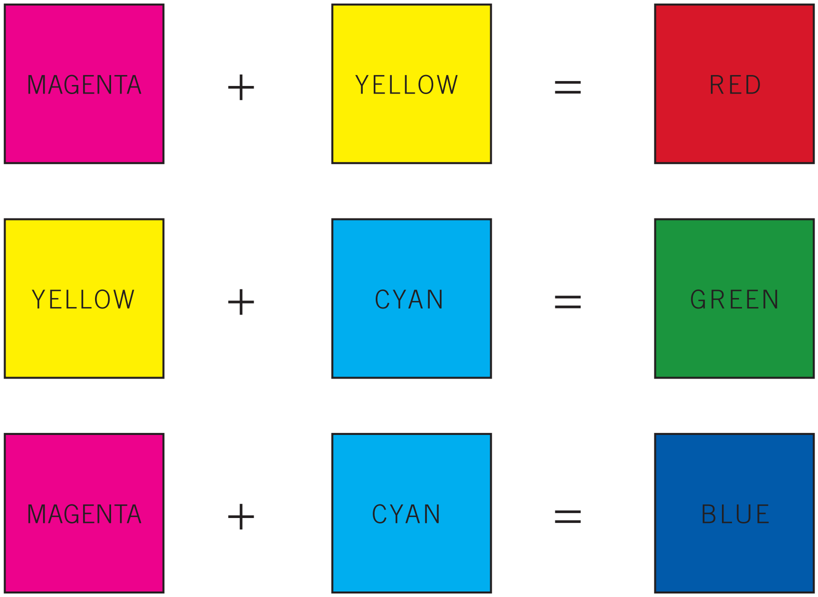
Magenta and yellow mixed absorb green and blue light (and transmit red), red results.

Yellow and cyan mixed absorb red and blue light (and transmit green), green results.

Magenta and cyan mixed absorb green and red (and transmit blue), blue results.

The three process primaries combined produce a medium gray tone, so black is needed to give sharpness and depth to a color image. The black also works to produce shades and muted colors. The brilliance of a pure color is reduced by adding black in 6% increments.[2]

Figure 9-10.
Process Color Mixing



In CMYK printing the inks themselves are not actually mixed. Instead, each color is printed in tiny dots and as a separate step, called a *separation* or *color separation*. Printing the color dots in different densities enables the printer to achieve hundreds of colors using only four foundation inks. The dots are positioned at different angles to avoid a moire, or watermark, effect.

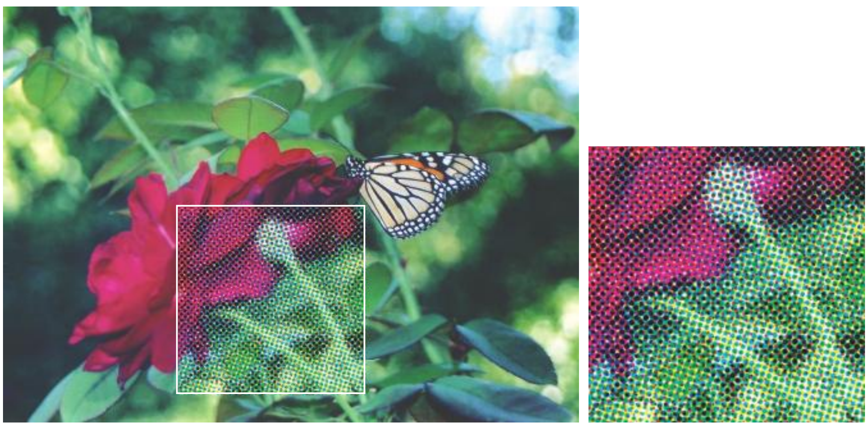


Figure 9-11.
Process Color Printing. Images in CMYK printing are made up of tiny dots. The dots are overlaid in different proportions to produce different colors.

Figure 9-12.
Color Separations. Each process color is printed as a separate step.

Most commercial printing is done on four-color presses using CMYK colors. Four-color process printing has some shortcomings. It does not produce clear colors in the orange range, many tints do not reproduce well, and gradations of color can be difficult to print (this book is printed in CMYK colors). Although excellent results can be obtained with CMYK colors using special printing presses called eight-color presses, only a few hundred of these presses are available worldwide. Dealing with the constraints of CMYK color printing is an ongoing challenge for graphic designers.

Pantone[3], a world leader in color technology, has responded to the limitations of CMYK printing with the introduction of a six-color process called Hexachrome®, which adds vivid green and bright orange inks as well as brighteners to the standard CMYK colors. Hexachrome® printing requires a six-color printing press, but these presses are reasonably available; thousands are in use in the United States alone. Computer printers are also available in six colors, but most day-to-day color printing, including commercial color printing, computer printer output, and color Xerography, is still done in CMYK color with its attendant limitations.[4]

CMYK and Hexachrome® inks are not the only kind of printing inks. Some printing is done with specially formulated solid-color inks called *spot colors*. A spot color is mixed individually, in the same way as artists' colors, before being applied to a roller. Special inks like Dayglo or metallics are printed in this way. These colors offer much greater depth and clarity of hue than process colors and because they are specially mixed, the number of possible colors is nearly limitless. However, since each color must be mixed and printed separately, printing with more than one or two spot colors is costly.

Spot colors are difficult to translate into CMYK printing. CMYK printing has a limited color range, and spot colors do not. Some colors can be produced in either medium, but most spot colors converted to CMYK printing lose their depth and vibrancy. Hexachrome® offers, if not a limitless range, at least a greatly extended one, and, in addition, a result on the printed page that corresponds more closely to the brightness of a design developed on screen. A graphic design that has been printed in Hexachrome® will be closer in appearance to its screen original than any other currently available process.

Hand printing is associated more with fine art printing than with high-volume print production. In general, it employs subtractive colorants in the same way as other artists' media. True hand printing, like hand silk-screen or block printing, is used commercially in a small number of ways. Luxury goods like custom wallpapers or high-end home furnishings or fashion textiles are occasionally hand-silk-screen or hand-block printed, but the cost of these techniques on a large scale is prohibitive. Some techniques in block printing and silk-screen have been adapted to machine printing and even to the use of CMYK process colors. Silk-screen in particular is in common use for printing onto fabric.

Figure 9-13. *Commercial Silk-screening.* Silk-screened wallpaper has a richness of surface not found in machine printing. *Image of "Compton Court II©" courtesy of First Editions Wallcoverings & Fabrics, Inc.*

Endnotes

1 Webster's 1987, page 620.
2 Warren 1996.
3 PANTONE® and other Pantone, Inc. trademarks are the property of Pantone, Inc.
4 Pantone, Inc., reprint from October 1998 edition of Electronic Publishing. PennWell, 1998.

Chapter 9 Highlights

- A design medium is a means of translating images, ideas, and colors from one kind of visual experience to another. Renderings and models are the principal way in which new product and color ideas are communicated to potential buyers. In all fields of design visual thinking and presentation takes place in (at least) one medium when the color of the product is achieved in an altogether different way.

- Most of the time, the form, surface, and color of an object are understood together as a single experience. Natural materials have random gradations and shadings that many consumers find attractive and can have color added without losing the attributes that make them appealing in the first place. Man-made materials in general need color added to make them attractive to consumers. Color can be introduced directly into the raw material before the start of the manufacturing process, chemically bonded to the surface of a material, applied as a coating at a late stage of manufacture, or colored using a combination of these means.

- Traditional artists' media are substances made up of an inert vehicle, or base, that contains (or carries) the colorant. Dyes are colorants in solution. Dyes penetrate the material they color and bond with it on the molecular level. Pigments are finely ground particles of colorant suspended in a base. Pigments "sit" on a surface rather than bonding with it. Many modern synthetic colorants bridge the traditional distinctions between dyes and pigments.

- Each medium has a limited number of colors that can be used alone or mixed together to extend its range. In order for two colors to produce a new hue, their colorants must reflect a wavelength in common. An experienced colorist mixes new colors based on the mixing affinities of specific tube or jar colors within each medium.

- Tinting strength is the relative quantity of a color needed to produce a perceptible difference when mixed into another color. Different colors within the same medium will vary in tinting strength.

- Process colors, or CMYK, are the principal medium of the printing and reprographic industries. The process primaries are cyan (blue-green), magenta (red-blue), and yellow, and are used with black. Process magenta absorbs green and transmits red and blue. Process yellow absorbs blue and transmits red and green. Process cyan absorbs red and transmits blue and green. When a process primary is laid on white paper, some wavelengths reaching it are absorbed and others are transmitted to the paper surface below. The white surface reflects the wavelength reaching it back through the ink "filter," and that color reaches the eye.

- Process primaries mix into the secondary colors that do not correspond to the colors that result from mixing artists' colors or the mixing of light. Magenta and yellow mixed produce red. Yellow and cyan mixed produce green. Magenta and cyan mixed produce blue. The three process primaries combined produce a medium gray tone. Black is needed to give sharpness and depth to a color image.
- In CMYK printing each color is printed in tiny dots as a separate step called a color separation. Printing the dots in different densities enables the printer to achieve hundreds of colors using only four inks. Most color printing, including commercial color printing, computer printer output, and color Xerography, is done in CMYK color.
- Some printing is done with specially formulated solid-color inks called spot colors. A spot color is mixed individually in the same way as artists' colors. A six-color process called Hexachrome® adds vivid green and bright orange inks as well as brighteners to CMYK colors. Hand printing is associated more with fine art printing than with high-volume print production. In general, it employs subtractive colorants in the same way as other artists' media.

10

The Medium of Light

Then and Now / Images of Light / Lost in Translation / The Screen Display / Color Management / Color Display Modes / Presentation: Screen and Print / Color on the Web / Web Color Coding / Emerging Media

Now that we have the machines let us, instead of imitating former products and techniques, try to design goods that are characteristic of machine production—do not let us imitate former designs. Let us, with the help of these technical aids, produce the new.
—Gregor Paulsson, Design and Machinery 1919

Less than a generation ago the advent of computer-aided imagery created a revolution in the studio workplace. The new medium offered designers for the first time the opportunity to explore a variety of solutions without constraints of time or cost. Countless changes in the shape, size, and pattern of images and colors became possible without the time-consuming effort of reworking by hand. Visual ideas could be saved in memory or on a storage device at any point, so that discarded images were readily available for reconsideration or future use. Images could be sent between locations instantaneously, with absolute fidelity and without concern for loss or damage in transit. The speed and ease of design production meant that staffing needs could be reduced. Conversely, computer drawing gave freelance designers the tools to compete with larger organizations. The time, labor, material, and space-saving advantages of the digital medium translated directly into greater profitability for both designer and manufacturer.

Present-day imaging technologies and design software have capabilities unimaginable even a short time ago. Programs that offer an illusion of three-dimensional space and movement through it are commonplace. The same problem can be addressed by users in remote locations working simultaneously. For all of these reasons and more, the computer is now the near-exclusive means of drawing in the design industries.

Then and Now

The revolution in drawing medium paralleled a revolution in communication. The Internet, conceived in the 1960s as a means of communication for national defense, rapidly expanded into a new and seemingly limitless public broadcast medium. Made up of countless computers and their connections, the Internet swiftly became a series of interconnected networks that made it possible for information to be accessed and shared on a global basis.

The World Wide Web (the Web, or WWW) is an enormous sub-network of the Internet that offers text, images, motion, sound, and interactive communication to businesses, organizations, and individual users. The Web provides access to millions of information sites, or pages, that are linked in such a way that users can move between them with ease. Access to the Internet and the WWW is accomplished through paid providers called ISPs (Internet Service Providers) that enable individual access to the information superhighway.

By 2003, a not-so-distant "then," it had been estimated that 55% of United States households had Web-connected computers. The incidence of Internet use was weighted by factors like region, affluence, ethnicity, education, and age. By 2009 that estimate had risen to over 80% of households, with the number of hours spent on the Internet influenced by the same factors. There is no reason to think that the expansion of Internet access or the power of the World Wide Web has peaked. The phrase "computer-literacy" will, within the foreseeable future, become as meaningful as "literacy."

For information seekers, there is no longer any need to adhere to a broadcaster's schedule, or wait for a periodical to be published or a library to open. Information, whether about a consumer product, an academic or technical question, or just about current news or weather, is available 24 hours a day, 365 days a year. For vendors, the magnitude of the potential audience is breathtaking.

Images of Light

A *graphic* is something written or drawn. A graphic image can be as simple as a black and white drawing or text or as complex and richly colored as a Botticelli Venus. It may or may not include drawings, text, photographs, and color, but no matter what it consists of, it is a means of communication.

Graphic design is the arrangement of forms and colors into a composition whose purpose is to deliver information, to draw attention, or both. Graphic design is often called, perhaps more accurately, *communication design*. Communication design is only one field in which screen drawing is the medium of choice. Architects, engineers, and interior designers; package designers, product designers — all use drawings to convey design ideas. Until the recent past, renderings were made in subtractive media like pencil, ink, gouache paint, watercolor, or marker. Hand-colored rendering are now a rarity. Every field of design employs drawing, and every field, with rare exceptions, employs drawing in light.

If screen drawings are graphic designs made in light, the color monitor is the designer's canvas: an empty picture plane awaiting the input of visual information. Among the principal uses of screen drawings are:

- The preparation of technical drawings
- The preparation of materials for printing, like books, periodicals, advertising flyers, and packaging
- The preparation of renderings for sales or production purposes
- The design of Web pages that must convey information about products; as online catalog
- The design of Web pages intended only for on-screen viewing and not associated with a physical product

The ways in which colors can be used to better communicate ideas — to improve the readability of text, or to create an impact, a special effect, or color harmony — are no different in drawing with light than in traditional media. What *is* different about designing in colors of light is that the colors must be selected not only with an eye to best resolving the immediate design problem, but also with consideration of its end use. If the drawing illustrates a product, can colors on the screen be made to "match" the product? Will the on-screen image end up as printed material, or will it be viewed only on a monitor? If the image is meant only for on-screen viewing, will it be seen on one screen, or on many? If on many screens, how many, whose, and what kind?

Josef Albers wrote about the interaction of colors in subtractive materials like paints and color papers. Designers today must navigate the interactions that exist between additive and subtractive colors; between light and substance. The monitor screen is a matrix in which three modes of color mixing can be in play at the same time: the red-yellow-blue-based colors of design thinking, the red-green-blue-based colors of working in light, and the cyan-magenta-yellow-based colors of process printing.

Figure 10-1. *Modes of Color Mixing*. Designers today must be familiar with (at least) three different modes of color mixing.

Today's technology demands of the user a constant adaptation to change. Hardware and software are in states of continual development. Changes take place so rapidly that nearly anything written about hardware or software is outdated before it goes into print. Future developments in the way that the colors of light are delivered and mixed on the screen will not affect the nature of the medium itself. Like every medium, light offers the designer a mix of advantages and disadvantages. Working successfully in color on a monitor screen means understanding the capabilities of the light medium: what it can do, and what it cannot.

Lost in Translation

The challenge of transposing a color idea from one medium to another is not new. Printed colors, for example, are not exactly the same as product colors; designers strive only to get the closest possible match. But even as technologies of imaging and the capabilities of software move forward at a dizzying pace, a crucial difference between computer renderings and those produced by traditional media is often overlooked. The computer is the drawing instrument and the screen its blank page, but the *medium* is light. *Computer rendering means that much of the time the designer draws and paints in additive colors images of things that ultimately will be experienced as subtractive colors.*

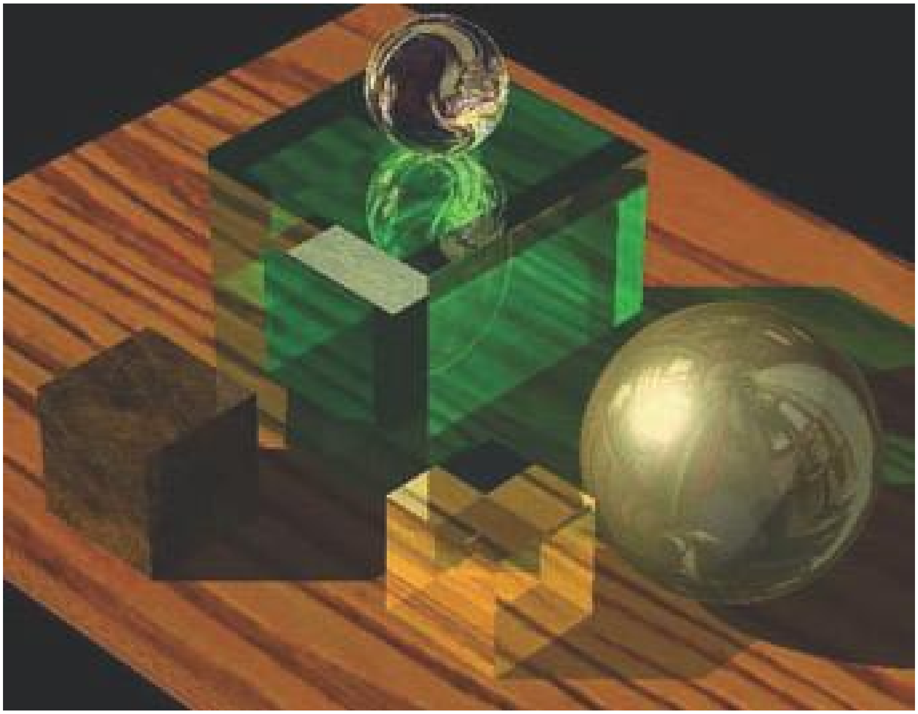
Working in light can be an intoxicating experience. Colors are vibrant, even brilliant, and mutable at the click of a mouse. But colors seen as light are experienced differently from the colors of physical objects. The colors of an object are seen as scattered, or reflected light, and reflected light is inevitably reduced to some extent. Some light is lost as the light travels from the source to the surface, and more is lost as the light travels from the surface to the eye. An additive color that is the putative "match" of a subtractive color —a screen color that represents a printed or product color—will inevitably be sensed as more brilliant on the screen than in life or on a printed page.

Many screen images include representations of real-world objects. The things that most impart distinction and vitality to the colors of objects—variations in surface, variations that occur from the use of different colorants or changes in ambient lighting—do not occur on a screen. They can be simulated, but the complete experience of color, with its attendant sense of the *tactile* quality of an object, is absent in the medium of light. Although vision is the primary sense used to identify objects and surfaces, the sense of touch is closely associated with it, as every PLEASE DO NOT TOUCH sign in a museum reminds us. An image made in light is a vision-only, single-sensory experience.

Reflected colors also seem more natural. Human beings are predisposed to understand reflected color as "real." The surface of an object scatters light in distinctive ways that contribute to the way that colors are perceived. Colors on a monitor screen, unmodified by surface, have a uniformity of effect. The direction from which light originates matters as well. In nature, general (white) light that comes from an angle 45° above or behind the viewer is sensed as the most natural. Light emitted by a monitor screen reaches the eyes from a direct frontal position.

The brilliance of colored light can be used to advantage in illustrating certain kinds of surfaces. Additive color and the capabilities of drawing software combine to great effect in the rendering of reflective materials. Screen drawings of materials like glass, polished metals, laminates, and high-gloss paints are particularly successful.

Figure 10-2.
Screen drawing
Digital drawing is perfectly suited to rendering reflective surfaces. *Digital drawing courtesy of Professor Ron Lubman, Fashion Institute of Technology.*



Materials with textured or matte surfaces like unpolished stone, natural woods, and textiles are more difficult to display. Pattern and color can be represented, but the way in which a textured surface reflects light is not easily conveyed. Textiles are particularly problematic. Color fields on a screen can be broken into areas of dark and light to suggest texture, but because the light that reaches the eye comes from only one direction, the characteristic flat brilliance of additive color persists.

Only computer drawing raises the issue of transposing colors from substance to light, and no other medium is in such widespread use. Good results can be achieved, but perfection is not possible. The best that can be achieved on a screen is a color that approximates its real-world counterpart. "Virtual" reality means "almost" reality.

The Screen Display

Successful color rendition on the screen begins with the selection of hardware and software that best meets a designer's particular needs. Every color image on a screen requires the interplay of platform, hardware, and software. Each platform—the combination of a particular type of computer and a particular operating system—has features that enable it to perform certain tasks better than others.

Software is designed to operate on a specific platform. The two platforms in most widespread use, PCs (personal computers) and Macs (Apple Macintosh) offer different capabilities. The display differences between competing products is small and is likely to continue to diminish. Mac and PC design programs are equally available, although Mac programs continue to dominate the design market, probably in response to designers' preference for their more intuitive operation.

Images on a monitor screen are created by the distribution (pattern) and strength (brightness) of light emitted at different wavelengths. The range of colors that a monitor displays is called its *gamut*, or *color gamut*. There are limitations to the color gamut of any monitor, but today's typical consumer-marketed monitor can display so many colors that its capability approaches the range of human color vision. *All monitors, however, display only additive color: wavelengths of light directly to the eye.*

A monitor screen is made up of individual elements called pixels ("picture elements"), which are the smallest units of the screen display. The pixels are arranged as a vertical and horizontal grid. Each pixel is made of up three components that can be triggered by an electrical impulse to produce the additive primaries, red, green, and blue. The voltage of the impulse applied to each pixel determines what color is displayed. Mixing the light emission *within* each pixel allows a full range of hues to be displayed. A pixel emitting both red and green light, for example, displays yellow, which is the mix of the two.

Each pixel on the screen can be altered in hue, value, and saturation. Pixels are measured as dpi, or "dots-per-inch" (or ppi, "pixels-per-inch"). The higher number of the dpi, the greater the screen's resolution (ability to show detail.) The number of ways in which a pixel can be *altered*—the total number of colors that a monitor is capable of displaying—is determined by its *bit-depth*. A bit is the smallest element of electronic information that a computer can use. The more bit-depth a monitor has, the more pieces of information—the greater the number of colors—it can display.

The earliest monitors had only a 1-bit depth and displayed only black and white. The first generally marketed color monitors had an 8-bit depth, enabling them to display 256 colors. The 24-bit-depth monitor, now standard for consumers, can display 16,777,216 variations in color, but as a practical matter only about 20,000 are available for design purposes, a number that is adequate for most tasks. The rest are there—and are necessary—to make smooth gradations between colors.

A 24-bit-depth monitor is sometimes said to be capable of displaying "true color," implying that the range of its gamut is comparable to human vision (and also that there is such a thing as "true color" at all.) While the best monitors can display an enormous range of colors, none can display all of the colors within the range of human vision.

The first monitors in general use were cathode ray tube (CRT) monitors. These were the original television or computer monitors, bulky forms that occupied considerable space. The inside of the screen of a CRT monitor is coated with a grid of phosphors, substances that emit light when they are bombarded with electrical energy. Each pixel contains phosphors that emit each of the three primary colors of light (red, green, and blue) when it is excited by an electrical impulse. An electron gun at the back of the monitor bombards the phosphor grid with a constantly moving stream of electrical energy at a variety of frequencies and the phosphors glow in different colors, depending on the electrical stimulus.

The CRT monitor has been displaced by the LCD, or liquid crystal display. LCD monitors, which also employ pixels, were developed originally as flat screens for laptop computers. Today they are found as monitors for personal computers and televisions as well as laptops. LCD monitors are lightweight and take up only inches of depth on a work surface, a combination of features that makes larger screens practical. They are also more energy efficient.

Figure 10-3.
The LCD Monitor. The flat screen LCD monitor is used for all design tasks. *Image courtesy of The Stevenson Studio, www.thestevensonstudio.com ©2005*

An LCD monitor displays color when light passes through pixels that are filled with liquid crystal and red, green, and blue filters. Light, typically fluorescent light, is provided behind the liquid crystal matrix and the filters within each pixel bend (refract) the light to produce spectral colors. Since each pixel has three components (red, green, and blue) and each is represented by 8 bits, the total bit-depth of an individual pixel is 24 bits. By varying the voltage of electrical stimulus, the hue intensity of each pixel can be extended to 256 steps. Combining the pixels (256 X 256 X 256) allows a display of more than 16 million colors. Because colors on an LCD screen are seen as wavelengths of light, not as a glow emitted by phosphors, the colors produced are close to true spectral hues.

A limitation of early LCD monitors was their extremely restricted viewing angle. As soon as the viewer shifted away from the ideal angle, contrast was lost and colors diminished in clarity. The newest LCD monitors have greater sharpness and although the viewing angle issue persists, it is much improved. There is also a current trend toward the use of LEDs (light-emitting diodes) as the backlight source for LCD monitors. LED backlighting is brighter than fluorescent and has the advantage of enabling a wider color gamut than is available on present screens. Steven King, a pioneer and expert in the field of computer color, predicts that within the near future all high-end LCD monitors will be produced with LED backlighting.

Monitors with up to 48-bit color are available for specialty purposes like professional image editing, high-end workstations, and medical imaging. These monitors use only the 24-bit-depth for colors; the additional bits are for special effects like animation or translucency. Very-high-end CRT monitors are still made for these purposes, but according to Paul Gagnon of DisplaySearch, a provider of display trends data, LCDs are supplanting these as well, and CRTs will disappear from the market within a very short time.

The LCD monitor, with its lighter weight, spectral color, lower energy consumption and rapidly advancing technology, has replaced the CRT, but that does not mean that there is a single all-purpose-perfect hardware or ideal software. Different manufacturers provide different quality levels and different capabilities. Every screen and mode of display has its own quirks, its own negative and positive aspects. With the rapid and constant developments taking place, selecting a monitor that is best for specific design tasks requires careful consideration of capabilities and features that are currently available.

Color Management

The difficulties inherent in displaying subtractive colors in an additive medium are so universally acknowledged that an entire industry is devoted to solving them. *Color management* tools are needed not only for colors on the screen that must correspond to product and print colors, but also for images that will be presented as light alone.

Hardware and software tools help to reduce the difficulties of making acceptable matches between screen colors and print or product colors. Color standards are a basic tool. A standard enables the designer to make constant comparisons against the same color at each step in the design process. Standards for color printing are most often quality-controlled printed colors on paper. A standard can also be a sample of actual product, like a metal finish, a wood finish, a yarn, or a lipstick. Standards are essential to maintaining a high level of consistency between the color of a product or printed page and its representation on-screen.

In order for screen colors to best represent the color of an actual product, the source of any image must also be standardized. This means that the color of the product and any photograph, transparency, scanned image, or rendering of it must conform to the same set of standards. Unless all of these elements can be cross-referenced to the same standard, even the most carefully prepared screen image is potentially unreliable as an indicator of product color.

A number of sophisticated color management devices are available for purposes of *calibration*. To calibrate a monitor means to adjust it so that specific combinations of red, green, and blue signals produce specific colors on the screen. The resulting screen colors can be calibrated to a set of equally standardized subtractive colors—print or product—so that the on-screen image is a reasonably accurate prediction of how colors will appear in their final form. The spectrophotometer of a color management tool measures and brings into synchrony the wavelengths of reflected color from the standard and those of emitted color from the screen.

At times the user must consider the end-use lighting condition of the standard before calibrating, because subtractive colors appear differently under different sources of ambient light. Colors on a monitor will also drift over time, even a relatively short period of time, so monitors that are used for design purposes need to be calibrated on a regular basis or before doing critical color work.

Figure 10-4. *Color Management.* ColorMunki™ exemplifies the multipurpose calibration product. *Image provided courtesy of X-Rite.*

ColorMunki™ exemplifies a multipurpose color managment product. ColorMunki™ offers a program that can synchronize palettes to specific design programs, match screen colors to PANTONE® CMYK and spot color inks, create and name custom color palettes, calibrate colors for large screen projections. A colorimeter is used to calibrate the monitor with its software. A spectrophotometer captures the color of any material or image and creates an on-screen match; it even evaluates subtractive colors under different light sources. Versions are available for both Mac and PC platforms, and there is also a product for photography.

Calibration is also done to standardize colors between devices. A group of monitors can be calibrated to display like colors, but within limitations. Different platforms handle color slightly differently. Not all colors seen on a Mac, for example, will appear the same on a PC. Even within the same platform, in order for all viewers to see the same colors, their monitors must calibrated in the same way—standardized with each other as well as with the source of the color image. Monitors that share the same display capabilities can be calibrated identically so that a number of monitors display the same colors with a high level of consistency. Monitors that have different display capabilities cannot be calibrated in this way, but they can be calibrated to the same set of standards, so that a reasonable level of display consistency can be achieved. With care and good calibration, it is possible to display images that are reasonably close in color to a controlled audience of any size.

Reference standards and color management tools provide the designer with the means to make acceptable matches between additive and subtractive colors, particularly between screen and print colors. Not all users take advantage of these tools. In some studios a match between screen color and product is still made laboriously by matching each color individually by eye. Several design professionals interviewed confessed to shifting screen colors deliberately *away* from a standard in order to provide a livelier image for on-screen presentation. Even with the best tools, there are no absolutes. *No matter what standards and tools are employed, the ultimate decision on the quality of a match—and the best presentation—is made by the designer's eye.*

Color Display Modes

Bit-depth determines only how many colors a monitor is *capable* of displaying. The software determines how many colors are actually displayed and how colors are mixed on the screen. There are three different ways in which design programs display and mix colors. Generally, all offer a basic assortment of hues, a range of grays, and black and white presented as a box or circle called the color palette. Colors on the palette are mixed in one of three possible ways: the CMYK mode, the RGB mode, and the HSB mode. Each kind of display has a limited number of available colors and it is this range of colors that makes up its particular gamut.

Dithering is a capability of some graphics programs that extends the range of colors in software that has a limited color palette. Dithering takes advantage of the human eye's tendency to "mix" colors that are similar to each other. In a dithered image, colors that are not available in the gamut are approximated by pixels in a mixture of two or more similar colors from those that are available. Dithered images, particularly those with relatively few colors, often have a fragmented, grainy appearance. The number of available colors in the gamuts of most present-day software has made dithering less of a concern than in the past.

Figure 10-5. *Dithering.* Dithered images can have a fragmented, grainy appearance.

The *CMYK mode* of color display imitates the results of mixing process colors. Each color in the CMYK mode represents a color of process ink (cyan, magenta, yellow, black). The CMYK display mode facilitates working on the screen for print production.

Figure 10-6. *Color Display Modes.* Each color in the CMYK mode represents a color of process ink. *Adobe product screen shot reprinted with permission from Adobe Systems Incorporated. ©2010 Adobe Systems Incorporated. All rights reserved. Adobe and Photoshop is/are either [a] registered trademark[s] of Adobe Systems Incorporated in the United States and/or other countries.*

A bar display allows the user to select cyan, magenta, yellow, or black as a percentage of the screen display. When two of the CMY colors are mixed without black, clear colors and tints result. Three CMY colors mixed in equal percentages (with no black) make a middle gray that has a chromatic basis. Muted colors are achieved using this CMY gray mix and manipulating one or two colors until the desired effect is achieved.

Achromatic gray scales are made by manipulating percentages of black (K) alone. Black is used for making hues darker: one or two of the CMY colors plus black yields shades. The black-based gray that is mixed into a pure hue will make it darker, not more muted. There is a difference in mixing colors between a CMYK light display and CMYK inks. In mixing inks, black is used in producing both shades and muted colors.

Varying the percentages of the three hues and black enables the designer to display on screen a full range of colors including most hues, values, and saturations. The CMYK display mode requires little new thinking about color mixing for designers who are familiar with process colors.

The *RGB mode* of screen display parallels the behavior of light. It is used to create images that will be viewed only as light display, such as Web pages or DVDs. In the RGB mode each of the light primaries, red, green, and blue, is displayed as a separate bar, called a channel. Each channel has an 8-bit depth so each primary can be displayed in 256 variations, and these multiply to the possibility of millions of variations.

The user selects each color for mixing in a range from no display (0%) to full display (100%). When 100% of each of the three light primaries is mixed, the result is white. When none (0%) of each primary color is mixed, the display is black. If 50% each of red, green, and blue is displayed, the result is a middle gray. Varying the relative percentages or red, green, and blue in RGB mixtures enables the user to view most hues, values and saturations.

Figure 10-7.
Color Display Modes. The RGB mode of screen display is used to design for the medium of light. Colors are mixed exactly as light is mixed. *Adobe product screen shot reprinted with permission from Adobe Systems Incorporated. ©2010 Adobe Systems Incorporated. All rights reserved. Adobe and Photoshop is/are either [a] registered trademark[s] of Adobe Systems Incorporated in the United States and/or other countries.*

RGB mixing does not correspond to either of the two most familiar forms of subtractive mixing, artists' colors or process colors. It is not suitable for printing because the number of colors that it is possible to generate in the RGB mode is much greater than can be printed using the CMYK process and many of the colors that it displays cannot be printed. The RGB mode is most directly associated with working and viewing in the medium of light.

The *HSB mode* of display stands for hue, saturation, brightness (value). The HSB mode displays a color map. Next to the color map are three boxes, one each for hue, saturation, and value. Each box has a range of numerical values. The user first selects a color from the map, then instructs each of the boxes to modify that selection in hue, saturation or value. Unlike the CMYK or RGB modes, it does not correspond to either additive or CMYK subtractive color mixing. Although colors are mixed on the screen in a way that is familiar to users of traditional media like paints, the HSB mode actually requires learning to mix light in a way that is associated only with digital design. Software for the HSB display mode is also marketed under different names: HSL (hue, saturation, lightness) and HSV (hue, saturation, value).

Figure 10-8. *Color Display Modes.* Colors in the HSB mode are mixed as separate steps—one each for hue, saturation, and brightness (value). *Adobe product screen shot reprinted with permission from Adobe Systems Incorporated. ©2010 Adobe Systems Incorporated. All rights reserved. Adobe and Photoshop is/are either [a] registered trademark[s] of Adobe Systems Incorporated in the United States and/or other countries.*

Presentation: Screen and Print

The level of color management needed during design development depends a great deal on the end use of a drawing. For example, the computer is superbly suited to the preparation of technical drawings, where pinpoint accuracy is critical. The degree of precision that is essential in plans drawn for constructing a ship, an airplane, or a building is now unimaginable except as digital drawing. In general, however, technical drawings use color only to make diagrammatic situations easier to read. These drawings may employ color, even require it, but accuracy in rendering a specific color—a certain red, or a particular blue, whether the drawing is presented on a screen or printed—is rarely essential to their purpose.

Renderings, on the other hand, call for close attention to color. Renderings have two distinct purposes. First, they are used to visualize new products and/or new colorings. The designer's rendering is the first, and sometimes the only, opportunity for a manufacturer to decide whether a new product or color offers a competitive edge, so it is critical to decision-making that its colors represent as closely as possible the colors of the finished goods.

The second purpose of renderings is to convey product design and color from the design studio to the manufacturing floor. The use of preproduction renderings is industrywide, ranging from the design of cars and appliances to textiles and building materials. A rendering can be sent electronically to a manufacturing location, where the colors in the image are “matched” to actual materials. Alternatively, the selection of some material—yarn, metal, plastic, or stone—precedes the rendering and the artist begins work from a physical or samples. The factory uses the screen rendering as a color placement guide. In either case, the task of the renderer remains the same: to replicate in light, as closely as possible, the hue, value, saturation, and surface qualities of a subtractive material.

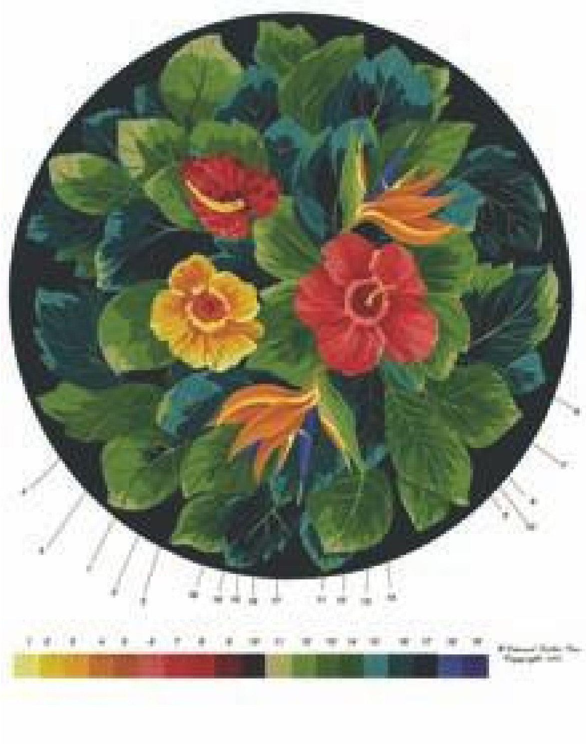


Figure 10-9.
Traditional Rendering. A gouache rendering of Edward Fields’ carpet “Tropique” is shown to a client for approval, then sent from the salesroom to an overseas factory for fabrication. *Image courtesy of Edward Fields Carpet Makers.*

Figure 10-10.
Computer Rendering. Computer-generated drawings have overtaken hand-rendering for carpet designs. Edward Fields’ carpet “Blythe Bridge” is rendered on the computer. *Image courtesy of Edward Fields Carpet Makers.*

Renderings may be printed or may be presented only on a screen. A good representation of real-life color on the screen is as vital for small-scale undertakings as for large ones. The architect or interior designer making a laptop presentation to a private client is just as much at the mercy of the screen's ability to display the colors of paints, textiles, and finish materials as the designer of a hotel complex making a PowerPoint presentation to a group of investors.

The most extensive efforts to manage the disparities between on-screen color and product have been made for the printing industry. When a screen drawing is done for printing purposes the drawing is made in light, but the final medium is printing ink. The great majority of printers, whether personal or commercial, produce continuous fields and shadings of color using process color inks, and these colors are a standard in graphic design software and many color management tools. Limiting the colors on the screen to the capabilities of CMYK printing helps to ensure that the screen design will be reproduced in print as closely as possible.

A *bitmap* is an image made of dots, or pixels, that correspond exactly to information in the computer memory. A computer printer separates the digital image into four bitmaps, one each for cyan, magenta, yellow, and black. Each bitmap duplicates the number and pattern of pixels of that color in the computer memory. The bitmaps are printed out as dots and overlaid in different densities in an effort to simulate as closely as possible the way in which an image is created on a commercial printing press. There are large-scale computer printers that use CMYK colors with additional bitmaps to extend the color range, adding grays and lighter cyan and magenta inks. There are also families of computer printers that do not use CMYK inks. Hexachrome® printers are available, although these are not in widespread use. Another type uses colored wax, which is more opaque than process inks and reflects light differently. Another, the dye-sublimation printer, uses CMYK inks on a plastic film that is fused at high heat onto paper. The heat causes the dyes to melt, or sublimate, onto the paper, which reduces the dot quality of typical ink printers. Dye sublimation prints appear more like photographs than typical computer prints but are costly to produce.

Color on the Web

Every Web page is a graphic design—a contained arrangement of forms and colors. Whether it is static or in motion, or accompanied by sound, its entire reason for being is to communicate information. Whether or not a Web page will be successful in *attracting* viewers to that information depends in large part on the appeal of its page design and colors.

A much greater range of colors can be seen on-screen than can be printed. A screen image is potentially richer in color than any other means of presentation. Screen colors can be displayed with near-perfect consistency between monitors when they share the same platform, software, and are calibrated to the same set of standards. This kind of controlled situation might be found in a design studio, for example, including its remote locations.

The consumers who retrieve images from the Internet are not a controlled audience. They regularly experience color-display inconsistencies, although they are not necessarily aware of them in those terms. The consumer may be using a Mac, a PC, or some other platform. Home monitors vary in type and quality. The average person is unlikely to calibrate or use color standards. Since color depends on the display properties of the *receiving* monitor, there is no guarantee that the page designer's carefully planned colors will reach the home screen with any fidelity. Even viewers who do calibrate do not necessarily employ the same calibration software or set of standards. Realistically, the colors of a Web page cannot be assumed to arrive their destinations intact. They will be somewhat different on each screen they reach.

A major function of Web page design is to provide information about consumer goods and services. Many Web sites include on-screen catalogues, and these pages must convey as closely as possible the form, colors, and surface of goods and materials. No matter how well designed a product may be, success in the marketplace depends in great part on its color appeal. Consumers rate color as the single most important factor in making a decision to purchase. It is critical to sales that the screen display represent as closely as possible the colors of the product. If a drawing or photograph on a Web page has not been calibrated to a product or print standard before being broadcast, the number of opportunities for color shifts to take place between the product and its arrival on a home screen increases at each step.

Consumers encounter the same issue in reverse. As more and more items are purchased from online vendors, more decisions to buy are made based on images of light. A sweater the purchaser identifies as blue on a screen is likely to be returned if it arrives in green. Careful Internet vendors remind potential purchasers that the color of the product may be different from the image on their screen.

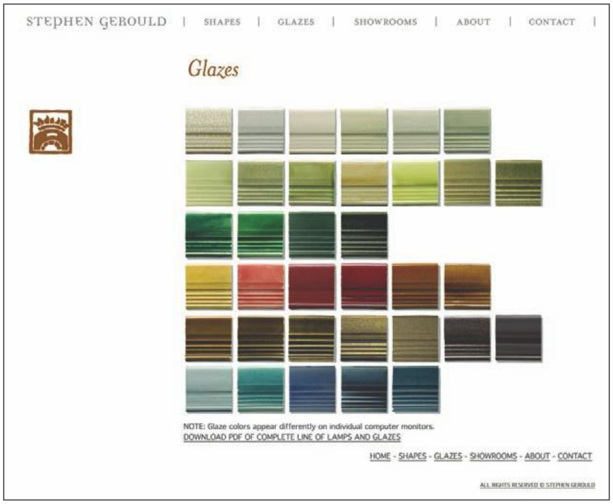


Figure 10-11.
Selling Color on the Web. Stephen Gerould reminds potential purchasers of his handmade ceramic lamps that the color of the product they receive may not be the same as the image on their screen. *Photography by Carolyn Schirmacher from the Website of Stephen Gerould Handmade Ceramic Lamps.*

When a Web page offers information only and does not represent a product, the page itself *is* the product. While it is likely that there will be a disparity in color between the designer's colors and the viewer's colors, only one step—from designer's screen to the receiving screen—separates the two. Because the image does not represent subtractive color, color differences between the sender's screen and receiver's screen are less likely to matter.

Web Color Coding

HTML (hypertext markup language) is the principal programming language of the Internet. It is the language in which Web pages are designed. Web design colors are specified by several widely used systems of coding.

Computer function is based on binary code. Colors in many widely used programs are specified in binary code by their relative proportions of red, green, and blue. Binary color coding identifies 256 steps, designated 0-255, of red, green, and blue (in that order) for each pixel of the on-screen image. Each color is coded by its intensity within that pixel, with 0 representing no color and 255 representing maximum color. Black, for example, has no color and is 0,0,0. White has all three primaries equally and at full intensity and is coded as 255,255,255. Red is 255,0,0; green is 0,255,0, blue is 0,0,255. Binary codes for the secondary colors of light follow logically: yellow, the mix of red and green, is 255,255,0; cyan, made of green and blue, is 0,255,255; magenta, made of red and blue, is 255,0,255. Any color in the available gamut can be coded in this way. A color described as "orange-orange red," for example, is 255,102,0: full red, with enough green (because green and red mixed equally yield yellow) to make it into an orange.

Colors for Web graphics are also described using the *hexadecimal* system. The specification for each color in the hexadecimal system is based on a 16-symbol code consisting of the numbers 0 through 9 and the letters A through F. Each color is specified by two symbols as a percentage of each primary emitted in red, green, blue order. The full specification is called a hex triplet. No emission at a wavelength is indicated as 00; the maximum possible emission as FF. Black is therefore 00000, or no light emission; white is FFFFFF, or all primaries emitted equally. Red is indicated as FF0000; green as 00FF00, and blue as

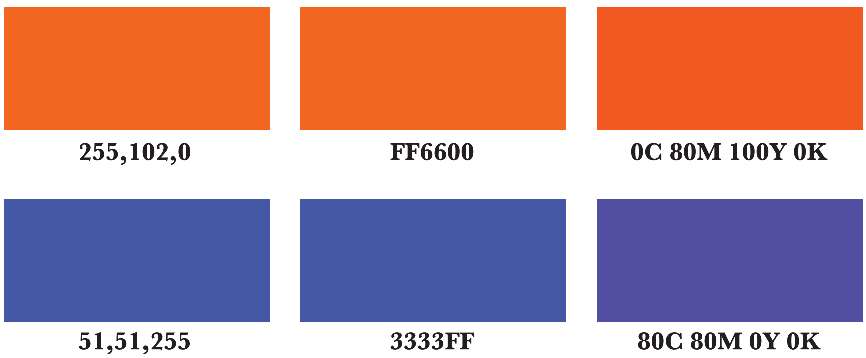


Figure 10-12. *Screen colors are coded in more than one way.* A screen color can be specified in binary coding, hexadecimal coding, and by its closest CMYK print equivalent.

0000FF. Yellow is FFFF00—the secondary color mix of red and green, with no blue. Any color in the available gamut can also be coded in this way. The "orange-orange red" that is 255,102,0 in binary code is FF6600 in hexadecimal code.

Neither binary nor hexadecimal coding offers perfect color transitions. Middle codes may or may not be middle colors, and color intervals are not reliable by number. The designers eye is still necessary to make decisions about final colors and sequences.

Colors that have been specified in binary code can be converted to hexadecimal code, and vice versa, by using readily available charts or formulae. Both binary and hexadecimal coded colors are also specified by names that are generally acknowledged by most Web browsers. The names help Web designers to locate some colors more easily than by their hex triplet or binary designations, but the number of names includes only a small fraction of available colors.

Early color monitors had very limited bit-depth. A tool that helped designers working on material for Internet distribution was a group of RGB colors called the Web-safe (or Netscape) palette. These colors were (and still are) available online, in book form, and were an option in older design programs. The Web-safe palette identifies 216 colors in a full range of hues that are reasonably consistent for viewing on both Mac and PC platforms and monitors with a limited (256 colors) display range. Restricting colors to this palette gave designers some assurance that colors reaching the home computer would be displayed as a reasonable approximation of the original.

The colors in the Web-safe palette were selected for their probability of consistent transmission, not for design application. Many of the colors within each hue group are quite similar. For the greatest chance of success in reaching a wide variety of platforms and monitors, a designer

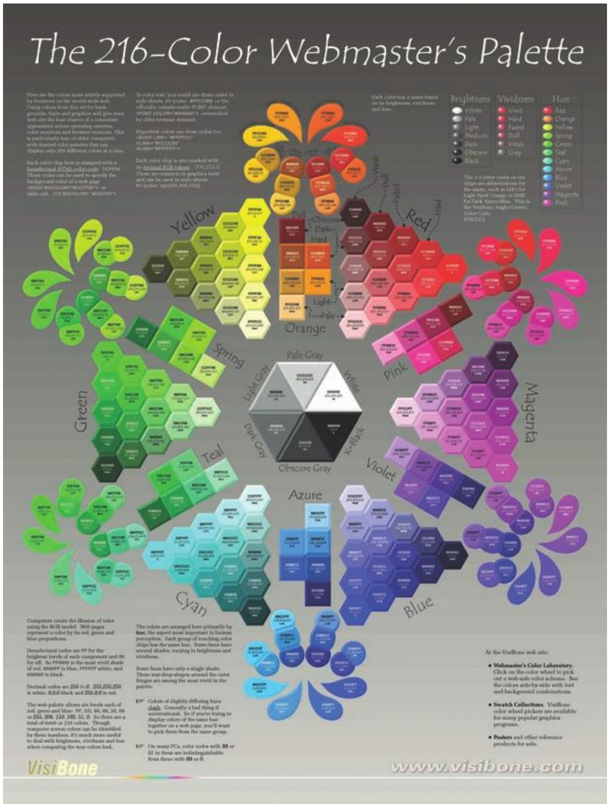


Figure 10-13. *The Web-Safe Palette.* VisiBone offers the Web-safe palette on line and in print as charts, books, folders, and cards. *©2005 VisiBone.(This figure does not use VisiBone's 8-Color printing process to match computer screen color.)*

working within the Web-safe palette had to avoid using colors with subtle differences within the same hue group, and the limited number of colors made working within the Web-safe palette less than satisfying. Advances in the capabilities of hardware and software and the proliferation of monitors with greater display capability have made the Web-safe palette less important than in the past. Many writers consider their use no longer necessary. This topic is covered admirably in a number of articles and books specific to Web design, notably those by Lynda Weinman and Bruce Heavin.

Outside the limits of the Web-safe palette lies an enormous range of available colors, each of which must be individually specified for each flat color situation. Selecting colors from this vast number can be overwhelming. Reducing a gamut to a smaller palette, a limited group of colors with preselected and designated relationships, helps to make color selection a more manageable process. Many of these preselected color palettes are on offer to designers, both as software and as free or for-purchase charts, each representing its own organization, set of preferences and point of view.

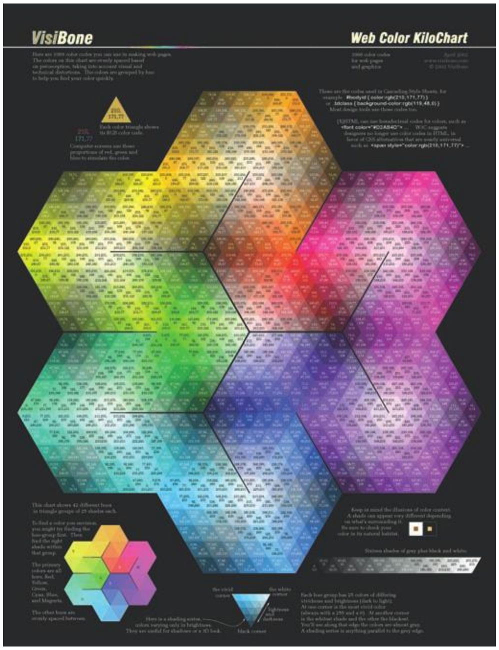


Figure 10-14.
Limited Palettes. Visibone offers a preselected palette of 1068 colors that are outside of the Web-safe palette with their binary code designations as a reference tool for Web page designers. *© 2010 VisiBone's 1068-Color reference chart. (This figure does not use VisiBone's 8-Color printing process to match computer screen color.)*

One of the problems associated with a fixed color palette is that colors needed to display a specific image may not be available in the palette, while many of the available colors may not be needed. A fixed palette containing mostly variations of pink, for example, would not be well-suited for images that do not contain pink. The present trend in software, which assumes a 24-bit depth monitor, is the use of an adaptive, or optimized color palette: one in which the available colors are based on how frequently they appear in the original source image. An image based on an optimized palette is much more likely to be closer to the original source image than any other approach, and an optimized palette eliminates dithering.

Emerging Media

One of the most exciting new technologies, not yet available in color, is the electronic paper display. The electronic paper display is a bridge between subtractive and additive media. It begins with a printing ink, or e-ink, that is made up of tiny capsules that contain both black and white particles. The particles are suspended in a clear fluid within the capsules. In one current formulation the white particles have a positive electrical charge; the black ones have a negative charge. The capsules are suspended in a medium that is then applied to a surface that is laminated to a layer of circuitry. When positive and negative charges are applied selectively, the capsules rotate so that either black or white becomes visible on the surface. The pattern of dark and light is established by the pattern of the circuitry and is controlled by a display driver.

A recent development in color display is four-color LCD technology, which adds a clear, strong yellow to the red-green-blue of each pixel. Advertised on the Web and in print as "four-primary-color" technology, it is said to expand the gamut of available screen colors enormously while also deepening blacks. Four-color technology is currently marketed only for television monitors but seems certain to enter the computer monitor market within the near future.

Endnotes

1 Rodemann 1999, page 170.
2 Developed by E-ink Corporation.

Chapter 10 Highlights

- Monitor screen images are created by the distribution (pattern) and strength (brightness) of light emitted at different wavelengths. Monitors display only additive color. There is no perfect way to translate an additive color to a subtractive color, or the reverse.

- Pixels are the smallest units of the screen display. Each pixel can be triggered to emit red, green, and blue light. Mixing light within each pixel allows each pixel to be altered in hue, value, and saturation.

- Each platform and monitor has its own color display capabilities. The range of colors that a monitor displays is its color gamut. Screen colors can be displayed with consistency between monitors only when they share the same platform, software, and are calibrated to the same set of standards. Consumers who retrieve images from the Internet constantly experience color-display inconsistencies.

- An LCD monitor displays color when light passes through pixels that are filled with liquid crystal and red, green, and blue filters. A early limitation of LCD monitors was their restricted viewing angle, now much improved.

- Color standards are samples that enable the designer to make constant comparisons against the same color at each step in the design process. Color management tools are needed for colors on the screen that must correspond to product and print colors, as well as for images that will be presented as light alone.

- To calibrate a monitor means to adjust it so that specific combinations of red, green, and blue signals produce specific colors on the screen. Screen colors can be calibrated to equally standardized subtractive colors. Calibration is also used to standardize colors between different devices.

- Software determines how many colors are displayed and how colors are mixed on the screen. The CMYK mode of color display imitates the results of mixing process colors. The RGB mode of color display parallels the behavior of light. The HSB mode of color display requires learning to mix light in a way that is associated only with digital design.

- A bitmap is an image made of pixels. A computer printer separates the digital image into four bitmaps, one each for cyan, magenta, yellow, and black; each of which duplicates the number and pattern of pixels of that color in the computer memory.

- Colors are specified in binary code by their relative proportions of red, green, and blue. Colors for Web graphics are also described using the hexadecimal system, which specifies each color based on a 16-symbol code consisting of the numbers 0 through 9 and the letters A through F. Neither binary nor hexadecimal coding offers perfect color transitions. Middle codes may or may not be middle colors, and color intervals are not reliable by number. Colors that have been specified in binary code can be converted to hexadecimal code, and vice versa, by using charts or formulae.

- The Web-safe (or Netscape) palette, now considered obsolete by many, is composed of 216 colors in a range of hues that are reasonably consistent for viewing on both Mac and PC platforms and on monitors with a limited color display range. The trend in software suggests an adaptive, or optimized, palette in which the available colors are based on how frequently they appear in the original source image.

- A recent development in color display is four-color LCD technology, which adds yellow to the red-green-blue of each pixel. Another new technology, not yet available in color, is the electronic paper display. The electronic paper display is a bridge between subtractive and additive media.

11

The Business of Color

The Color Industries / Producing Color / Color Sampling / Color Forecasting / Color and Product Identity / Palettes, Color Cycles, and History /Traditional Colors / Influences on Palettes

The chief business of the American people is business.
—Calvin Coolidge

From a business point of view, design has a single purpose: products are made to be sold. A product sells because consumers find it more attractive than others like it. The decision to buy has as much to do with the purchaser's perception of a product as it does with the product itself. An item may be purchased because it seems comfortingly familiar, or because it makes a fresh and positive impression at the point of sale. No matter now well-functioning a product may be, to succeed it must be both attractive and memorable. A great part of success in sales is a result of good looks.

For consumers, color is the largest single factor in a decision of whether or not to make a purchase. Market research indicates that 90% of consumer purchases are the result of a deliberate search, and that only 10% of purchases are made on impulse. And of the planned purchases, 60% of the decision to buy involves color.[1] Large-scale purchases like automobiles are generally given some time and thought, but it has been estimated that in a supermarket aisle, the product packaging has about 20 seconds to attract a buyer.

Color is more than just a means of attraction. According to Color Marketing Group, a professional color research organization, the use of color expands readership: color advertisements are read up to 42% more than similar ones in black and white, and color on a page both accelerates learning and increases comprehension. Colors increase brand recognition[2], which is crucial in a competitive market. Because colors have such a profound influence on sales, aesthetic decisions about color can become secondary to marketing ones. For designers, color means business. But what determines marketable colors? How are they selected, and by whom?

The Color Industries

Color not only *means* business; it *is* a business.The color industries are major, international, and widely varied. Manufacturers of consumer goods depend on them for support in product development and marketing, color technology, and environmental issues. Chemists and engineers create new colorants and the means to apply them. Testing laboratories determine that colorants are safe for the buying public. Research organizations explore consumer color preferences and analyze, chart, and publish observed color trends. Psychologists explore the potential for positive and negative reactions to colors by the buying public.

Advances or changes in one industry create a need for adaptation in others. Companies are increasingly interdisciplinary. Businesses that once specialized in a single field now extend their involvement to others. Pantone, for example, is so attuned to developing screen technologies and color marketing that it is involved in the development and manufacture of calibration tools and software, forecasting consumer color preferences, and a myriad of other color-related activities.

Producing Color

A foundation of the color industry is the manufacture of subtractive colorants: interior and exterior paints, furniture finishing materials, printing inks, ceramic glazes, automobile finishes, textile dyes, and colorants for numberless other materials. The manufacturing process is both art and a science; primarily, but not exclusively, the science of chemistry. Each color agent is a chemical mix with specific properties that make it compatible with the material it is meant to color. The necessity of working with legally permissible colorants adds a layer of complexity to the manufacturing process. Environmental concerns dictate that producers of every type or use of colorant stay current with constantly changing federal and local regulations.

Some colors may be difficult, or even impossible, to produce for particular products. CMYK printing, for example, lacks clear colors in the orange family. Bright, clear, reds are difficult to produce in ceramic glazes. Substrates also matter. Linen fiber, for example, does not dye to bright colors, while silk takes dyes brilliantly. Designers in every field are constrained by colors that are available to them. They must consider what is possible before selecting what may be desirable.

Color Sampling

Many times a single product is produced in a range of color choices. Some finishes are simply flat or glossy color; while others may display color shifts and special reflecting characteristics. In either case successful marketing requires that consumers be provided with a convenient and accurate way to make a selection. Colwell Industries, a century-old company, is the largest producer of color merchandising tools for decorative (and other) products. Colwell's processes exemplify the cutting-edge technology needed to create color samples that simulate the colors and finishes of real products. The charts and display materials that they produce range from interior and exterior architectural coatings to cars and cosmetics.

Colwell sampling charts are not conventionally printed, and only rarely are they available as samples of actual product.* Instead, paper grounds are coated with minute particles of metal, plastic, rubber or other substances to approximate the substrate of the real product. Car finish sample charts, for example, are made with a metal powder sprayed onto paper, followed by a coating of color lacquer. Colwell's chemists formulate colorants and finishes and its computers generate the mixing formulas, but even at this level of technology the human eye makes the final decision. Colwell President Bill Byers states it perfectly: "Color is an art, so a human eye is always needed."[3]

The care taken to duplicate color and finish does not attempt to address the additive-subtractive color issues of Internet shopping, but according to a Colwell spokesperson, metamerism is addressed in the laboratory. Although metamerism is unavoidable in some situations, Colwell strives for the closest sample-to-product match under a variety of light sources, a consideration that is increasingly important as new lamp types come into general use.

* Farrow and Ball, a British paint manufacturer, is a notable exception. It provides color charts made from actual paints.

Color Forecasting

A consumer economy relies on a constant demand for the new, including new colors. This demand originates at both ends of the market. Consumers want a fresh look, and producers make a conscious effort to step up sales by offering goods in new colors. Manufacturers depend for their survival (or at least for their profitability) on their ability to anticipate which new colors will be preferred by the purchasing public. And while this has always been true for the makers of short sales-life products like cosmetics and apparel, it is now true for all consumer goods. Even electronic devices, once available only in industrial black or gray, can now be purchased in "fashion" colors.

Nowhere do psychology, color, and marketing interact more closely than in the area of consumer color preferences. Hundreds of organizations and individuals provide (among other services) research and prediction of incoming color trends for target markets and target industries. These individuals and organizations provide manufacturers with an increasingly vital service called *color forecasting.*

Figure 11-1.
Forecast Colors.
The colors for youth, Fall and Winter 2011-2012, as forecast by The Color Association of the United States.
Image courtesy of the Color Association of the United States.

Manufacturers and vendors rely on color forecasting to enhance their ability to compete for the consumer dollar. Forecasters provide information and guidance on the next wave of color demand, consulting on everything from hair colors and flowers to appliances and buildings. Organizations like The Color Association of the United States (CAUS), Color Marketing Group (CMG), and the Pantone Color Institute identify and predict color trends through a variety of methodologies: observation and reporting by individual members, meetings and workshops, scientific consumer testing, consumer surveys, and by analyzing how consumers respond to a number of cultural forces.

Regional factors are also considered. Not all colors sell in all climates and cultures. Color forecasts address national trends, but they also target narrower markets. Design legend Jack Lenor Larsen noted that "because color forecasting works (it is, after all, self-fulfilling) we shall see more of it but it will, necessarily, be more focused."[4]

Figure 11-2.
Forecast Colors. A collection of fashion colors for the urban market. © *2010 by Color Marketing Group.*

Color forecasts are made for both short and long term, depending on the industry served. New palettes are arrived at either by a consensus of members or by smaller groups who meet on a regular basis to report their observations on "movement" in current colors: "toward a greener yellow," for example, as well as incoming and outgoing colors. The resulting palettes, published several times a year, reflect the focus of incoming color trends.

Color forecasting has its constraints. It must reflect public taste and direct it at the same time. People cannot be forced to like, or to buy, new colors. Individual consumers do not adopt all of the colors in a new palette. One reason for this, of course, is personal color preference, but a more determining factor is expense. It is costly to make color changes in big-ticket items like furniture and carpets. In home furnishings, completely new colors are purchased only when a household is undergoing a total renovation, or is a new household altogether. The same is true for apparel. Very few people discard all of their clothing from a previous year, and new items must work with the old. New colors and color combinations are most successful when they can easily be integrated into existing ones. New color preferences in the consumer market are not so much abrupt changes as they are movements from one palette into another.[5]

The advantage to manufacturers who follow the dictates of forecast colors is obvious: advance information about upcoming consumer color preferences means increased sales. The motto of Color Marketing Group is "Color sells...and the right colors sell better!" is followed by "CMG: Forecasting the Color of Profit."

Color forecasting benefits the consumer as well. When the fashion industry works within a similar seasonal palette, time-pressed shoppers find it easier to coordinate suits, ties, blouses, skirts, and cosmetics. When home-furnishings products are available in related colors, it is easy for the consumer to purchase compatible carpets, paints, wallpapers, building products, bed linens, china, and the multitude of other items that make a home.

Although color forecasting began in the United States, it is now a global phenomenon. American color forecasters consider international influences as a matter of routine and often seek out new ideas in exotic locales. Consumer color preferences in the Asian market are a current and lively area of study. Each year a European Hall of Prediction is held in Paris. London has its Colour Group, a panel with representatives from a variety of industries including paint, plastics, and automobiles.

Color and Product Identity

A second goal of color marketing is the attempt to establish a link in the public mind between a specific color and a specific product. Coca-Cola has its signature red; United

Parcel Service trucks (and uniforms) are brown. McDonald's arches are dependably golden. Color and form *together* can be extremely successful in establishing a color-product link. The scissors we like to use are orange. The chocolate-brown wrapper tells us that we are about to bite into a Hershey bar, not a Nestle's bar, whose blue-and-white wrapper suggests a dairy theme.

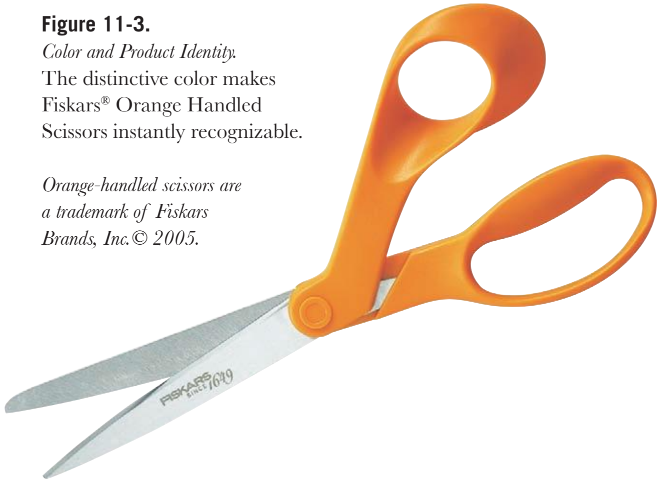


Figure 11-3.
Color and Product Identity.
The distinctive color makes Fiskars® Orange Handled Scissors instantly recognizable.

Orange-handled scissors are a trademark of Fiskars Brands, Inc.© 2005.

But color is a secondary identifier. Only rarely does a color alone identify a product. It becomes a leading visual cue to product identity when a form is both familiar and so generic that only the additional information of color creates an association.[6] A box is only a box, and unexciting to open, unless it bears the distinctive blue that signifies Tiffany and Company.

Some colors are so closely associated with a product that they have been trademarked. A trademark is a legal designation that protects a company's use of a specific image, color, or combination of these for a particular kind of product. It identifies the source of the product or service and distinguishes it from competing products of the same type. Owens Corning, for example, has trademarked a particular pink for insulation. Other manufacturers of insulation may not use it, but the color is available to makers of other products. Tiffany Blue, which resembles robin's egg blue, is a trademark owned by Tiffany & Co. The color is produced as a private custom color by Pantone as PANTONE number 1837, which is the year of Tiffany and Company's founding. Because it is a trademarked color, it is not included in any of the Pantone Matching System swatch books or Web color aids and its CMYK formula is closely held.

Trademarks are guarded fiercely by their owners. Disputes over trademarked colors have been so bitter and protracted that they have reached the United States Supreme Court. In one case the United States Supreme Court concluded that colors could constitute trademarks because although colors do not automatically evoke a connection to any product by themselves, they could take on secondary meaning in the course of use, and in this way a color could function as a trademark by identifying the source of a particular product.[7] Despite this decision at the highest legal level, the trademarking of colors remains an area of uncertainty. Other attempts to trademark colors have been challenged and have met varied responses from other courts.

Palettes, Color Cycles, and History

Color forecasting attempts to predict the upcoming popularity of single colors; it also predicts *palettes*. A palette is a group of colors that is characteristic of something, like a culture, an artist, or a time period. The characteristic earth browns, black, and sand colors of antique African textiles are a palette in sharp contrast to present-day folk cloths from South and Central America, whose exuberant colors result from modern dyes, but whose origins lie in the dazzling feather cloaks of Pre-Columbian civilization. No one would confuse Vincent Van Gogh's palette of sharp yellows and acid greens with Monet's soft pastel hues. A palette can also be a collection of colors given an assigned meaning, like a spring apparel line marketed as Easter-egg pastels, or a fall palette of rusts and bronzed greens.

Palettes shift in response to outside forces like new technology, exposure to new cultures, politics, and fashions. Certain palettes even provide a clue to the age of objects. Aniline dyes, which reached both the southwestern United States and Japan in the later nineteenth century, replaced the natural colorants that preceded them, and as a result, the age of Navajo blankets and Japanese prints can be determined in part by their colors.

Color cycles are stages in the continually shifting consumer preference for certain palettes. A color cycle represents a prevalence of certain colors in the context of a particular time (and place). The candy-pastel colored buildings of Miami Beach, which saw it greatest development as a resort in the third decade of the twentieth century, exemplify one aspect of Art Deco design. The muted colors of natural dyes are characteristic of the textiles of the late nineteenth century anti-Industrial-Revolution designer William Morris. A new turquoise colorant came on the market after World War II; architectural elements in salmon and turquoise suggest that a structure was built in the 1950s. The psychedelic colors of the 1960s have as a subtext, for better or worse, a belief in "better living through chemistry."

Tracking the rise and fall of color cycles began in the twentieth century. At the outbreak of World War I in 1914, American manufacturers of textiles for women's apparel became aware that they would not have access to the fashion colors dictated by Paris, at that time the fashion capital of the world. The Textile Color Card Association of America was formed and, within a short time, produced a first book of samples called *The Standard Color Reference of America*. This palette of 106 named colors, dyed on silk ribbons, was produced specifically as a color marketing reference for the women's apparel textile industry. The colors and their names were inspired by nature, by university colors, and the colors of Armed Forces uniforms.[8]

The number of colors in the *Standard Reference* grew steadily over time. Colors initiated by the apparel industry trickled down to home furnishings and, later still, to hard goods like appliances and automobiles. The demand for new colors created by color stylists at the top

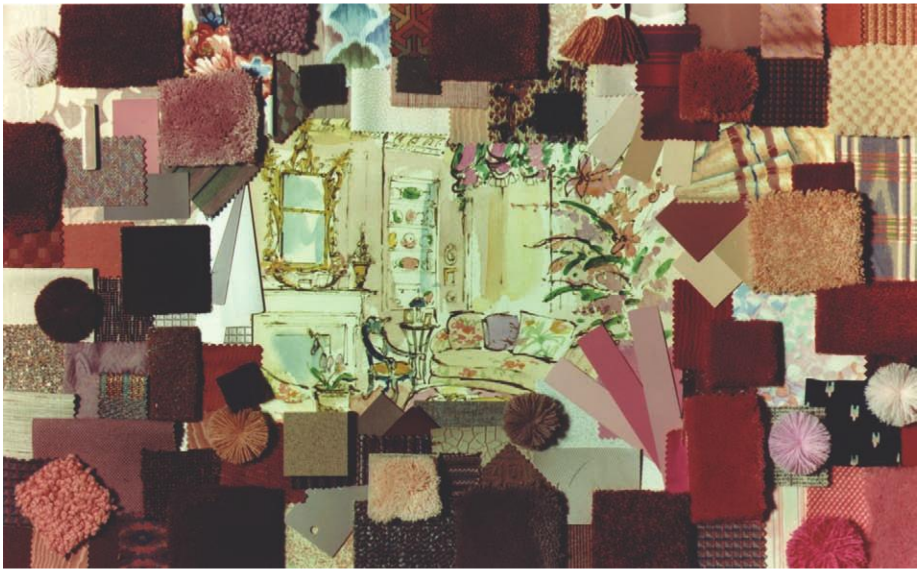


Figure 11-4. *Colors of the 1990s.* Kenneth Charbonneau's assemblage of colors from a multitude of manufacturing sources illustrates the colors of a decade. *Image courtesy of Kenneth Charbonneau.*

of the pyramid forced obsolescence of older goods. By the middle of the twentieth century, average color cycles were seven years or slightly longer, coinciding roughly with the decades. Fashion colors preceded other industries by about two years. Cycles tended to repeat in a roughly predictable fashion, from brilliant, full-saturation, colors to more muted ones, to neutral palettes, then back again to strong hues.

The women's apparel industry remained the focus of interest until the end of World War II, when other consumer-oriented industries became aware of the marketing power and manufacturing advantages of a controlled palette. The Color Association of the United States (CAUS), an outgrowth of the Textile Color Card Association of America, began to publish palettes for other industries: man-made fibers in the1950s, menswear in the 1960s, home furnishing in the 1970s, and, in the 1980s, international and environmental colors.

CAUS still produces a color reference of dyed silk standards, but its intended audience is now American industry as a whole. *The Standard Color Reference of America*, revised approximately every ten years, is marketed as being "indispensable to anyone working in clothing, interiors, graphics, or with government specifications." Now in its tenth edition, it offers 198 named colors favored by the American public, from Electric Blue through Jade Green, Schiaparelli Pink to Tangerine, West Point Gray to Yale Blue.[9]

As color increasingly became recognized as a force in marketing, other industries seized the initiative in originating palettes. The apparel industry lost its place as the sole arbiter of fashionable colors. It is no longer possible to isolate a single industry as the originator of color trends, nor is the length of a color cycle dependable. Color influences are now global. Consumer response to certain colors arises from any number of sources: pop culture, movies, museum shows, travel, and Internet communications, as well as from new directions in technology and industry. These influences initiate the trends that precede each new color cycle. Cycles are shorter and more transient. Color cycles for clothing are now estimated by experts in the field at eight months, and colors for home furnishings and interiors for three to five years.[10]

Traditional Colors

Consumers are a complicated crowd, varying by age, gender, income, education, social status, cultural background and geography. No matter how successful a current color trend may be, consumers at all economic levels continue to demand products in "traditional" colorings. There are traditional colors for some items of apparel—bridal wear and hunting gear are classic examples—but the market for traditional colors is particularly strong in home furnishings textiles.

Reproductions of period colors have not always been historically accurate, and they are not all accurate today. Colors oxidize (change after exposure to air and light) over time.

Figure 11-5.
Document Wallpaper. Arthur Sanderson and Sons wallpaper "Trellis" is available in the same colors as when it was introduced in 1864. *Image courtesy of Sanderson.*

Years of accumulated grime mute even the most durable colorants, and current levels of air pollution accelerate the deterioration. Not only are colors altered by soiling and oxidizing, the various colors in a composition alter at different rates. In a single textile or painted object, some colors change enormously over time and others hardly at all, so the original balance of the palette is lost. Many consumers think of the muted quality of faded colors *as* antique. Muted colors are often marketed as "traditional" in response to this common misconception. Sophisticated techniques of analysis now make it possible for the original colors of paintings, textiles, and decorative objects to be determined with greater accuracy. New methods of cleaning uncover close-to-original hues. Today there are wallpapers, textiles, and paints available that are near-perfect facsimiles of antique colors as they were when they were new. These reproductions are *document* (historically accurate) colors.

Present-day research and restoration approaches have caused a revolution in historic preservation. Building restoration, both interior and exterior, has taken on a new and controversial face as color accuracy supersedes the old conventions. When the Rose Room in the White House was refurbished during the Kennedy administration, there was a furor over the brilliance of its red-violet walls. The restored color duplicated the original, but it was shocking to a public used to thinking of period colors as subdued.

Influences on Palettes

From the beginning of time, new materials and new technologies—the *ability* to produce new colors—has been a powerful influences on palettes. Early man had only the tetrachrome palette; the red and yellow ochres, vine charcoal, and chalk that are still used by aboriginal cultures. The Egyptians, Minoans, Greeks, and Romans expanded the number of colorants in use until, by the Middle Ages, there was an enormous range of colors available for all of the arts—textiles, wall paintings, glass, ceramics, book illumination, and metals. Colorants in all cultures came from natural earths and organic materials. Earth colors were many and varied: blue from lapis and cobalt, orange from copper, red from iron, antimony yellow, cinnabar (sulfide of mercury, the prized and brightest red of the ancient world), and green from malachite. Others were animal or vegetable: murex purple from shellfish, red from madder, yellow from saffron, and blue from woad.

The colors and palettes of most cultures were determined by locally available materials, and early palettes had a sort of ethnic identity. Despite the hardships of early travel and trade, a slow but steady exchange of colors and color influences took place between East and West. Early Crusaders brought turquoise to Europe from the Near East; the Portugese brought indigo from India. Returning travelers, soldiers, and explorers added colors to the Western color canon.

The expansion of Western influence into Africa and the Near and Far East in the nineteenth century accelerated the exchange of colors between cultures. Colors and combinations remained typical of certain groups, but were no longer confined to them. The exchange of colorants and palettes through conquest and trade continued steadily until the middle of the nineteenth century, when the most significant change in the ability to create colors came about entirely by accident.

In 1856, an eighteen-year-old English chemist's assistant named William Henry Perkin was attempting to formulate synthetic quinine from coal tars when he noticed that his rags were stained a deep purple. Perkin had stumbled upon coal tar dyes. Perkin's first dye color, called mauvine, or aniline purple, was followed quickly by additional colors. Aniline dyes were so well received that he was able to retire at thirty-five, a rich man.

Perkin's accidental discovery of aniline dyes laid the groundwork for today's synthetic (man-made) colorants. The first aniline colors were followed briefly by a return to natural dyes, then a rapidly expanding array of synthetics quickly took over. Man-made colors are the norm in today's market. Natural dyes are so rarely used that they are found almost entirely in luxury handcraft goods, like Oriental carpets and Harris tweeds, and in some historical reproduction items. Chemistry, not nature, dictates the colors of the new millennium.

Advances in chemistry are only one influence on palettes. Political, cultural, and social events also bring new colors and combinations to the public eye. When Worth, the Parisian designer to the Empress Josephine, began to design for the English aristocracy as well as the French, French colors first crossed the English Channel, then the Atlantic. Colors in the second decade of the twentieth century felt the impact of Diaghilev's dazzling costumes for the Ballets Russe in Paris (1909), while artist-designers Leon Bakst, Robert and Sonia Delaunay, and Matisse also infused brilliant color into the palette of the early century.

World War I ended the primacy of the French in dictating fashion colors. The inspiration for fashion colors after 1918 came from the United States. The 1920s saw a number of concurrent palettes, among them a palette of silver, black, and white inspired by the glamor of Hollywood and America's growing industrial might. The Great Depression of the 1930s brought browns, drabs, and colors associated with warmth and comfort. Art exhibitions inspired new palettes: a 1935 Van Gogh exhibition in the United States created a vogue for sunflower prints in browns, greens, and yellows. During the World War II, facilities turned to war production, and patriotic colors were popular.

High-speed communication and the globalization of commerce have blurred the lines between palettes that once were representative of cultures and eras. The time lapse between new color influences and the consumer awareness of them is now so short as to be effectively nonexistent. Traditionally Japanese colors and combinations appear as often in Milan as in Tokyo. So-called "retro" colors have their own audience. No single source inspires the colors of fashion or industry. There have never been richer or more varied sources of inspiration available to colorists, and there has never been a larger or more varied audience for those colors. In the fast-paced, freewheeling climate of twenty-first century design, any combination is desirable, any combination is acceptable.

Figure 11-6.
Inspiration Without Borders. The brilliant palette of traditional Chinese architecture has inspired the colorings of internationally marketed products like textiles and ceramics. *Photograph by Alison Holtzschue.*

Colorists are blessed with this multitude of sources, but they're also faced with conflicting demands. The market appeal of colors is crucial to sales, and therefore to the design process. Colorists who compete in the global marketplace must provide innovative colorings, up-to-the-minute fashion colorings, and classic, timeless colorings of equal marketability. Creating new palettes for today's consumer economy is a high-wire act—an exhilarating balance between art and design, technology and commerce.

Endnotes

1. Rodemann 1999, page 170.
2. http://www.colormarketing.org/uploadedFiles/Media/The Profit of Color!
3. www.themanufacturer.com/us/detail.html?contents_id=3405 ©2010 **(byers)**
4. Linton 1994, page x.
5. Rodemann 199, pages 171–172.
6. Sharpe 1974, pages 8–9, 31–32, 43–45, 75, 98.
7. *Qualitex Company v. Jacobson Products Company, Inc.*, 514 U.S. 159 (1995).
8. Linton 1994, page ix.
9. Promotional material CAUS New York 2005.
10. PCI Paint coating industry article *Techno Color* posted 9/01/2001 and interview with Erika Woelfel of Colwell Industries.

Chapter 11 Highlights

- Color is the largest single factor in consumers' decisions to make purchases. The color industries are major, international, and increasingly interdisciplinary.
- Producers of colorants must work within the constraints of increasingly strict environmental legislation. Makers of color samples consider, but cannot prevent, problems of metamerism.
- Color forecasting organizations attempt to predict consumer color preferences for upcoming periods of time. A second goal of color marketing is to establish in the public mind a link between a specific color and a specific product. Some colors are so closely associated with a manufacturer or product that they have been trademarked.
- A color cycle represents the prevalence of a certain palette in a certain time and place. So-called "traditional" colors, like bridal white, maintain their symbolic meanings over long periods of time. Document colors are accurate reproductions of colors of an earlier time and place.
- Palettes are influenced by the availability of colorants, advances in chemistry, cultural, social, and political factors.

GLOSSARY

Achromatic Having no discernible hue or color.

Acuity *See* Visual acuity.

Additive mixture Color seen as a result of light alone.

Additive primaries The three wavelengths of light that must be present to yield white light: red, green, and blue.

Admixture An artist's technique in which a single color is mixed into all (or most) colors in a composition.

Aerial perspective *See* atmospheric perspective.

Afterimage A "ghost" image that follows stimulation of the eye by a single color when its complement is not present in the field of vision.

Aniline dyes A family of alcohol-and coal tar-based dyes discovered in the 1830's; capable of producing brilliant colors but not as colorfast as the azo dyes that succeeded them.

Analogous colors Colors adjacent on a color spectrum, sometimes defined as hues limited to the range between a primary and secondary. A group of colors including any two primaries but never the third.

Artists' media A family of subtractive media that selectively absorb and reflect light. Artists' media are composed of a liquid, paste, viscous, solid, or other base into which pigments or dyes have been introduced to form a transferable colorant, such as paint, dye, crayon, or chalk.

Artists' primaries The simplest colors of artists' subtractive media, from which all other colors are derived: red, yellow, and blue. Colors that cannot be further reduced into component parts.

Artists' spectrum The full range of visible hues as organized by Goethe: red, orange, yellow, green, blue, and violet; expandable to include any and all hues in between them. Also called the color circle or color wheel.

ASTM The American Society for Testing and Materials, now ASTM International, which provides standards for more than 130 industries, including standards for paints, dyes, and other colorants.

Atmospheric perspective A pictorial depth cue in which drawn objects appear farther away because they are illustrated as more muted and more blue than nearer ones.

Azo dyes A family of petroleum-based dyes developed in the latter nineteenth century, with greater color fastness than the aniline dyes that preceded them.

Base A liquid, paste, viscous, wax, chalk, or other substance into which pigments, dyes, or other colorants may be introduced to create a medium such as oil paint, textile dye, or crayon; also at times called a binder. *See* vehicle.

Beauty The quality of an object or experience that gives pleasure to one or more of the senses.

Bezold effect An effect in which all colors in a composition appear lighter by the addition of light outline, or darker by the addition of dark outline; also an effect in which a colored ground appears lighter because of a linear design in light line or darker because of a linear design in dark line. Bezold effect is sometimes too broadly stated as "an effect that takes place when changing one color composition appears to make all of the colors change." Also called assimilation effect and spreading effect.

Binary code colors A system for specifying colors for Web graphics by their relative proportions of red, green, and blue light emission.

Binder *See* base and vehicle.

Bit The smallest piece of digitally coded information.

Bitmap An image on the monitor made up of pixels that correspond exactly to the information in computer memory.

Brilliance The combined qualities of high light-reflectance and strong hue, typically found in saturated colors and strong tints.

Broken color A random distribution of patches or flecks of colors within a single area or field of vision.

Calibration The process of adjusting a monitor so that specific combinations of red, green, and blue signals produce specific colors on the screen.

Carried colors Colors in an image or design that are laid on the background.

Chroma A synonym of hue and color; the name of a color. Also, a term used to describe the relative presence of hue in a sample. A vivid color has high chroma; a muted color has lower chroma. *See* hue.

Chromatic Having hue or color.

Chromatic adaptation *See* successive contrast.

Chromotherapy The use of color for healing.

CIE The Commision Internationale de l'Eclairage; an organization that attempts to standardize color notation with regard to the colors of light.

CMYK display mode A mode of screen color display that imitates the results of mixing process colors. Each color in the CMYK mode represents a color of process ink (Cyan, Magenta, Yellow, Black.)

Color A category of visual experience including hue, value, and saturation. Also, a synonym for hue and chroma; the name of a color. *See* hue.

Colorant A substance that reacts with light by absorbing some wavelengths and reflecting others, or by absorbing some wavelengths and transmitting others. *See* artists' media and process colors.

Color chord A group of theoretically harmonious hues, expressed geometrically as rectangles or triangles overlaid on the artist's spectrum.

Color coding The use of color to differentiate between similar objects or ideas.

Color constancy The perception that the colors of familiar objects remain the same no matter what the general lighting.

Color cycle A period of time or stage in consumer preference for certain palettes; the prevalence of certain colors in the context of a particular time.

Color display mode The way in which a user mixes colors on a monitor screen. *See* HSB display mode, RGB display mode, CMYK display mode.

Color forecasting A service that provides manufacturers and vendors with information and guidance on upcoming consumer interest in certain colors and palettes.

Color gamut *See* Gamut.

Colorimeter A device that measures the red, green, and blue wavelengths of emitted light; used to calibrate computers.

Color management The process of synchronizing colors between two or more devices or media.

Color memory The ability to retain color in memory; also the association of colors with images or events. Some experiments have indicated that the presence of color adds additional information to memory so that an image seen in color is more easily recalled than the same image seen without color.

Color notation A system of letters and numbers used to organize colors

Color Rendering Index A rating scale meant to assess the ability of a lamp to render the colors of objects. Lamps are rated based on the degree of color shift that occurs when an object placed under the test lamp is compared to the same object under a reference standard lamp.

Color solid A representation of colors organized by hue, value, and chroma (saturation) as a three-dimensional form.

Color temperature In lighting, the measurable temperature in degrees Kelvin of any given light source. In color theory and description, the relative warmth (red-yellow-orange cast) or coolness (blue or green cast) of a color.

Colorway A specific combination of colors for a product such as a textile or wall covering that is available in more than one combination of colors; as "this wallpaper is available in a red colorway, a green colorway, and a gray colorway."

Color wheel A synonym for spectrum. Also, a term sometimes used to mean a multicolor spinning top devised by nineteenth-century scientist James Maxwell to demonstrate responses of the human eye to colors in motion.

Complementary colors Colors that lie directly opposite one other on the artists' spectrum. Each pair of complements includes the three primary colors (red, yellow, and blue) in some proportion or mixture.

Complementary contrast An effect of intensified hue difference that takes place when colors used together contain even a partial complementary relationship.

Complements *See* complementary colors.

Composition A complete entity, something meant to be sensed as a whole.

Cones Light-sensitive receptor cells in the retina that respond to color and fine detail.

Contrast reversal A variation of afterimage in which the "ghost" image is seen as a negative of the original image and in complementary color.

CRI *See* Color Rendering Index

Design Used as a noun, art fused with function in an object that will be produced by others; as a verb, the process of originating applied art.

Design concept A broad solution to a design problem without resolution of details.

Design process Procedure for solving design problems.

Dilution Changing a pure or saturated hue by lightening, darkening, or muting by the addition of black, white, gray, or its complement.

Display mode The way in which a user mixes the colors of a monitor screen display. *See* color display mode.

Dithering A grainy or broken area of color caused by the insertion by the software of small areas of similar colors within an image to approximate a color that does not exist in the gamut. *See* gamut, hexadecimal colors, and Web-safe palette.

Divisionism *See* optical mix.

Document color Color or colors in a reproduction textile, wallpaper, paint, or other product that accurately reproduce the color or colors of that product as they were when originally produced.

Dye (dyestuff) A colorant that is fully dissolved in a vehicle, such as water or other liquid; a colorant in solution. Traditional dyes in general were organic, but most modern dyes are synthetic (man-made).

Equilibrium An involuntary, physiological state of rest that the eye seeks at all times. Equilibrium occurs when all three (additive or subtractive) primary colors are present within the field of vision.

Even intervals Visually equidistant steps between three or more colors.

Field In carpet and flag design, the term for the background upon which colors are laid. *See* ground.

Filter A material that transmits some wavelengths of light and absorbs others.

Fluting A three-dimensional illusion in which a series of vertical stripes of uniform width appear to have concavity, like the channels of a Doric column.

Fugitive Easily fading or deteriorating color.

Full color *See* saturated color.

Gamut The full range of colors available in software and seen as the light display of a color monitor. Also used, less frequently, to characterize the range of colors in subtractive media.

Glitter Sparkle; sharp light reflectiveness with an impression of movement.

Gloss A highly polished, light-reflective surface quality.

Gradient A series of progressive intervals of colors so close that individual steps cannot be distinguished.

Gray scale A value series made up of intervals of gray, which may or may not extend to include black and white.

Ground The background against which colors, forms, or shapes are laid.

Harmony In color, the pleasing joint effect of two or more colors used together in a single composition.

Hexadecimal colors Colors within a system of specifying colors for Web graphics based on a 16-symbol code consisting of the numbers 0 through 9 and the letters A through F. Each color is specified by two symbols as a percentage of red, green and blue.

HSB display mode The HSB display mode (Hue, Saturation, Brightness) mixes light on the monitor screen in a way that is associated only with digital design. Software for the HSB display mode is also marketed as HSL (Hue, Saturation, Lightness) and HSV (Hue, Saturation, Value.)

HTML Hypertext markup language; the principal programming language of the Internet and the language in which Web pages are designed.

Hue The name of the color: red, orange, yellow, green, blue, or violet. Synonyms are chroma or color.

Hue intensity The saturation or purity of a color; its vivid versus dull quality. *See* saturation.

Illuminant mode of vision The presence of a viewer and light source only.

Image A representation or depiction of a person, animal, or object; also a form or shape seen against a ground. Images can vary from photographic likenesses to nonrepresentational forms that do not portray objects or natural appearances.

Incandescent light Light that results as a byproduct of burning.

Incident beam The beam of light leaving a light source.

Indirect color A secondary reflection of color that occurs when light from a general light source reaches a highly reflective color on a broad plane. The wavelength of color reflecting off the colored plane washes any surface that is positioned to receive it (that is, positioned at an angle equal to that of the incident beam leaving the general light source).

Intensity Sometimes used as a synonym for brilliance, or the strength of a hue. *See* hue intensity and light intensity.

Intermediate color A color on the spectrum between a primary and a secondary.

Interval A visual step between color samples. *See* even interval.

Iridescence An attribute of surfaces on which the hue changes as the observer's angle of view changes.

Lamp A device that emits light, or visible energy. The correct term for a light bulb.

Light Visible energy.

Light intensity The light-reflecting quality of a color. *See* luminosity and value.

Luminosity Literally, light emitted without heat. Used to describe the light-reflecting quality of a color. Luminous colors reflect light; non-luminous colors absorb light.

Luster Sheen; softened or diffused light reflectiveness on a surface.

Matte A smooth, dull, visually flat quality of surface.

Maximum chroma The strongest possible manifestation of a hue.

Medium The means by which something is transmitted. *See* artists' media.

Metameric pair Two objects that appear to match under one set of light conditions but do not match under a different set of light conditions.

Metamerism The phenomenon that occurs when two objects that appear to match under one set of light conditions do not match under a different set of light conditions.

Monochromatic Containing only one hue.

Monotone Color without variation. Used to describe two or more colors of very close hue, value, and saturation.

Motif A single, specific design element, an isolated and individual idea, form or shape.

Motion parallax A real-world depth cue that includes motion and time.

Motion graphics Drawings that include pictorial depth cues, motion, and time.

Negative space The area of a composition that is not occupied by motif or image. Negative space is often, but by no means always, the ground of a composition.

Object mode of vision The presence of a viewer, light source, and object.

Optical mix A new color that is seen as a result of the close juxtaposition of small areas of two or more other colors. Sometimes called divisionism. *See* partitive color.

Optimized palette A pre-selected, limited palette made up of colors that are found in the original source image.

Palette Literally, a board or plate upon which colors are mixed. Palette describes a group of colors used characteristically by an individual artist or designer; colors present in a specific design, group of designs, or body of work; or colors of a particular era.

Partitive color A new color that is seen as a result of the close juxtaposition of small areas of two or more other colors. *See* optical mix.

Pastel An apparel-industry term for colors diluted by white to high or middle value; also, clean tints with little or no muted quality.

Pattern A design composition formed by the reoccurrence of motifs. Pattern may be geometric or fluid, regular or random.

Physical spectrum The full range of visible colors of light as postulated by Newton: red, orange, yellow, green, blue, indigo (blue-violet), and violet.

Pigment A colorant that is finely ground and suspended as minute particles in a vehicle. Traditionally, pigments were inorganic (earth colors), but modern chemistry has blurred this distinction. Pigments in general are opaque.

Pixel One of the points of light that make up the picture on a monitor screen. The word derives from "picture element." The greater the number of pixels in a given area (the smaller and closer together), the higher the screen resolution.

Primary colors The simplest colors of the artists' spectrum; those that cannot be reduced or broken down into component colors: red, yellow, and blue. *See* artists' primaries, additive primaries, and process primaries).

Process colors A subtractive medium that selectively absorbs and transmits light. Yellow, cyan (blue-green), and magenta (red-violet) colorants that, when mixed or laid over one another, result in a wide range of colors for the printed page. Used with the addition of black in four-color (CMYK) printing.

Process primaries The simplest colors of process printing inks; those cannot be reduced or broken down into component colors: Cyan (blue-green), magenta (red-violet), and yellow. All hues in process printing are derived from these three inks. *See* artists' primaries, additive primaries, and process colors.

Pure color *See* saturated color and maximum chroma.

Reflected beam The beam of light reaching an object that is reflected back.

Rendering Used as a noun, a final drawing; used as a verb, the process of drawing a final image.

Resolution A measure of the sharpness and clarity of an image and extent and clarity of detail that can be seen. In a monitor image this is determined principally by the number of dots (pixels) per square inch: the more pixels, the higher the resolution. Resolution is used to describe printers, monitors and scanners.

RGB display mode The RGB (Red, Green, Blue) mode of screen display parallels the results of mixing light. It is used to mix colors for images that will be viewed only as monitor screen light display, such as Websites or DVDs.

Rods Light-sensitive receptor cells in the retina that are responsible for peripheral, less focused vision.

Saturated color The most intense manifestation of a color imaginable; the "reddest" red or "bluest" blue. A fully saturated color contains one or two of the primary colors but never the third. Saturated colors are undiluted by black, white, or gray. Synonyms are pure color, full color, or hues at maximum chroma.

Saturation The degree of purity of a color; its hue intensity or vivid quality, as opposed to muted or dull quality.

Secondary colors Colors made up of two primary colors. *See* secondary colors of light, secondary colors of artist's media, and secondary colors of process printing.

Secondary colors of artist's media A group of colors, each resulting from the mixture of two subtractive primaries: orange (red and yellow), green (blue and yellow), violet (red and blue).

Secondary colors of light A group of colors of light (additive colors), each resulting from the mixture of two primary color wavelengths: cyan (blue and green), yellow (red and green), and magenta (blue and red).

Secondary colors of process printing A group of colors, each resulting from the mixture of two primary colors of process color ink: red (magenta and yellow), green (yellow and cyan), and blue (magenta and cyan).

Shade A pure color made darker, or with black added.

Simultaneous contrast A spontaneous color effect that results from a physiological response of the eye to stimulation by one color only. The eye, seeking the presence of all three primaries in the field of vision, generates a "wash" of its complement onto any adjacent neutral area.

Single interval The smallest difference between samples that a viewer can distinguish; established by the individual's threshold. *See* interval and threshold.

Sparkle Sharp light reflectiveness on a surface, with an appearance of movement. *See* glitter.

Spectral colors Scientifically defined colors of light; additive colors that are measurable by wavelength.

Spectral reflectance curve The pattern of relative energy that a specific lamp emits at the various wavelengths.

Spectrophotometer A color managment tool that provides a wavelength-by-wavelength analysis of additive or subtractive color.

Spectrum The full range of visible hues. *See* artists' spectrum and physical spectrum.

Spreading effect *See* Bezold effect.

Standard A sample against which a color is matched.

Subtractive mixture Color seen as the result of the absorption of light; the colors of objects and the environment.

Subtractive primaries The primary colors of artists' media, the artists' primaries: red, yellow, and blue *See* artists' primaries and process primaries.

Successive contrast *See* afterimage.

Surface The outermost layer of a two- or three-dimensional thing; its "face" or "skin."

Synaesthesia A largely unexplained phenomenon in which one sense responds to the stimulation of another.

Tertiary colors Colors made of any mixture of the three primaries; "brown," or chromatic neutrals.

Threshold That point in vision at which an individual can just distinguish between two close samples.

Tint A pure color plus white, or made lighter.

Tone A nonspecific word referring to some change in a hue. Most often used to mean a graying, or reduction in saturation (chroma).

Transition A change that takes place in steps (or intervals) from one form, color, size, surface, or other element to another, different one.

Transparence illusion An illusion in which opaque colors are made to appear transparent, created by drawing two colors as if they overlap and placing an interval between them in the area of overlap.

Value Relative light and dark, with or without the presence of hue. High-value samples are light; low-value samples are dark.

Vehicle A liquid, paste, viscous, wax, chalk, or other substance into which pigments, dyes or other colorants may be introduced to form a medium such as oil paint, textile dye, or crayon. Also referred to as a base or binder.

Visual acuity Sharpness of vision, the ability of the eye to see detail.

Wavelength A pulse of energy that a light source emits at specific distances apart. Within the range of visible energy, each single wavelength is perceived as a separate color.

Web-safe palette A palette of 216 selected colors that are reasonably consistent for viewing on any operating system and monitor. With advances in imaging this gamut is now considered by many to be an unnecessarily restricted number of colors. Web-safe colors are non-dithering. *See* hexadecimal colors.

Weber-Fechner principle A mathematical series in which intervals between numbers are geometric (1, 2, 4, 8, 16, 32, 64, 128, etc.) in progression, each step twice the one before and half the one following. Weber-Fechner series are used to illustrate visual intervals, particularly intervals of value.

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