Experience of Color

Information About the World

Touching, tasting, smelling, hearing, and seeing—these are the ways we get our information about the world, about where we live and where we work. But the world of humans is primarily a world of sights, with 90 percent of what we know of the world coming to us through our vision.[1]

What we see is color. Objects, landscapes, faces all register in our brains through the light that enters the eye, sent to us from a luminous—or light-producing—object (such as a red-hot iron or a glowing incandescent light) or as light reflects off a nonluminous object (such as a tree or a table). The eye's retina absorbs the light and sends a signal, or sensation, to the brain. This sensation makes us aware of a characteristic of light, which is color.

The visual equipment we use to see light and its characteristic color is the same for everybody, and when it's working, it works very well—the National Bureau of Standards estimates that the human eye can distinguish over 10 million different colors. However, color does more than just give us objective information about our world: It affects how we feel. To know this, we need only recall how a string of grey, overcast days lowers our spirits or how working in a drab, dull room leaves us listless.

With so much of what we know and feel coming from what we see, you'd think we'd all be experts on color. In a way, we are. No one has to tell you what you're seeing or how you're feeling as you sit in the glow of a late summer sunset. But how would you describe the pink of that sky? Dazzling? Fleshy? Glistening? Iridescent?

The qualities we assign to our perceptions of colors—to the way they make us feel—are called indeterminate attributes. They cannot be measured; rather, they arise from our intuitive experience of color. These indeterminate attributes provide the mystery of color and range from the poetic language we use to express our perceptions of color to the psychological effects of color on our mood.

Determinate attributes are another matter. They can be measured by various instruments and include hue, value, and chroma—(as some describe them) warm/cool, light/dark, and brilliant/dull colors. They have given rise to optics, a branch of science that analyzes the mechanisms we use to perceive color—the rods and cones on the eye's retina—and colorimetry, which measures the color systems developed to precisely communicate color.

The mystery and the mechanics of color are tightly entwined. We seldom see a single color in isolation, completely independent from the influence of other colors or other external factors, such as the light source, the surface of the object, and the surrounding objects. Also, we never perceive color without the modifying influences of psychological and symbolic factors. In other words, our response to color depends on who we are and what our culture tells us certain colors should mean.

As simple as it may seem on the surface, color has a depth that is worth fathoming. The more we understand color, the more we can appreciate the joy it brings to our lives and the better use we can make of it. That use can be as focused as knowing what to put on in the morning in order to look our best or as broad as knowing how color in environments, particularly the office, can influence motivation and performance.

Sensing Color

Walk into an office and what do you see? Well, if your eyes are open, in one sense you see everything. Natural light streaming in through the windows and artificial light from lamps flood into your eyes and bounce off everything in the room and then into your eyes. But in another sense, you see only what you want to see—the carpet, done in the same lush green as the one you just installed in the family room; the fluorescent blue of the pin the receptionist is wearing on her red dress; the curious yellow of the reception seating fabric.

For centuries everyone, from Greek philosophers to Age of Reason scientists, considered only the first half of seeing—the mechanics. They believed our eyes were merely receivers. Sir Isaac Newton (1642-1727) called them "visual equipment" that measures light waves much like a clock measures time. Consequently, most research involved optics, the branch of physics that describes how light is produced, transmitted, detected, and measured.

The scientists of Newton's day regarded intellect as pure and sensory experience as morally suspect. That view was predominant until, about a hundred years after Newton, the German poet Johann Wolfgang von Goethe (1749-1832) began arguing for the roles the human eye and brain play in sensing color. Color psychologist Heinrich Frieling, writing about Goethe's philosophy, says the poet "felt that Newton and the physicists who supported him failed to do justice to the experience of color in our everyday life, its dynamic flow, which was as much a part of color as the mathematics of optics."[2]

The Poet's Balanced View of Color

Goethe's contemporaries scoffed at his emphasis on perception, the elements it involved (eye, brain, emotions, experiences), and his insistence upon the interdependence of science and art. Another hundred years passed before Goethe's views were appreciated. Over the last 20 years, color educators have revived many of Goethe's ideas and now credit him with anticipating much twentieth century research into color science and theory.

Perhaps it is appropriate that a poet should have helped us achieve a more balanced view of the complex activity of sensing color. As science professor Hazel Rossotti notes, "Not only are sensations of color affected by illness, injury and drugs, they depend on the area and shape of the object, its distance from the eye, its position relative to the eye, the intensity of the light, and the colors generated by the rest of the visual field. Nor is the sensation dependent only on what is in front of the eye at one particular perception. And, since our experience of color is affected by our memory, by our knowledge of what color some object really is, we could claim that our color sensations are, in a sense, influenced by a lifetime of visual experiences."[3]

The degree of complexity involved in sensing color is proof for many that it is active, not passive. Biologist Nicholas Humphrey believes the active nature of sensing color comes from our desire for pleasure and our need for survival: "If men take pleasure in looking at a particular sight or hearing a particular sound we may expect that the consequences of their doing so—whatever they may be—are beneficial, though the benefits may well be indirect and the beneficiaries may be quite unaware of them."[4] Humphrey adds that beyond helping us enjoy our lives, our ability to see color, like the glowing red of an ember or the heavy black of a threatening sky, could have evolved only because it contributed to our biological survival.

Light allows us to sense color. To a large degree, sensing color depends on four key factors: 1) the spectral energy distribution of the light, i.e., the conditions under which the color is perceived; 2) the spectral

characteristics of the object in terms of how much light it absorbs, reflects, and transmits; 3) the sensitivity of the eye in registering light and then turning it into electrochemical impulses and sending them via the optical nerve to the brain; and 4) the psychological factors, namely the experiences and the personality of the viewer, all of which affect how color is perceived.

Scientists define the first of these factors, light, as a form of radiant energy or, more precisely, electromagnetic energy, a category of energy that includes gamma rays at one end of the spectrum and radio waves at the other. The light our visual system responds to in the experience of seeing, called "visible radiant energy," is a very small portion of the spectrum, falling between infrared and ultraviolet radiation. Bands of visible radiant energy appear to us as color, and we call them light.

Surfaces Define the Colors We See

The second factor influencing our perception of color is the spectral characteristics of objects, sometimes called "surface" and "surround." How a surface reflects, absorbs, or transmits light and how the colors and textures surrounding the surface influence its color give us the information we need to understand the objects we perceive. They help us know an object's shape and location, although the interaction of surface and surround can also distort our perceptions—as when a yellow office makes the faces of the people who work in it appear jaundiced.

We experience the surface mode of color as part of a material or substance. The different visual sensations we get from viewing two table tops—one with a gloss finish, the other with a matte finish—illustrate the influence texture has on the character of color. Even though the color of the two table tops may be identical, the gloss on one will create an internal refraction, or bending of the light waves, making its color appear more brilliant than the color on the matte-finished top. Surface color can also be the result of a material's structure. Polar bear fur, blue jay feathers, and a kitten's blue eyes are actually clear. Their structures refract, or bend, the light that illuminates them to cause the colors we see.

The Eye Records Color Stimuli

In considering the third factor upon which our perception of color depends—eye-brain neurology—the focus turns from the world around us to the world within. Light, whether from a luminous object or reflected from the surface of a nonluminous object, enters our eyes and photochemically activates key nerve cells on the retinas known as rods and cones.

Rods operate at low light levels—for example, at night or in a darkened, windowless room—and sense blacks, whites, and greys, also called achromatic colors because they have no hue (the property of color that is perceived and measured on a scale ranging from red through yellow, green, and blue to violet). The cones in our eyes operate at higher light levels—for example, during the daytime or in a lighted room—and sense chromatic color, or hues. When the cones are active during the day, the rods are dormant. At night, the rods take over and the cones rest.

Three Types of Receptors Produce Our Colors

Humans see color with three types of reception systems (red/green-, yellow/blue-, and black/white-producing) from three types of cone photoreceptors (red/blue/green-making). Because we create all the colors we see from red-, blue-, and green-sensing cones, humans are known as trichromats. When one set of color-sensing cones fails or is missing, a form of color blindness occurs—either monochromatism (when only one of the three photoreceptors works) or dichromatism (when two of the three work). These dysfunctions are a gene trait carried by women and occur mostly in men—about eight of every 100 men suffer from some type of color blindness, while only one in every 200 women does.

Some creatures, such as surface fish, bees, and some birds, can see more colors than humans can because they have more color-making photoreceptors than we do. On the other hand, many mammals, except for humans, have poor color vision. The expression "to see red" comes from the anger of the bull as it charges the matador's red cape. In actuality, however, cattle have no cones in their retinas, so they can't perceive hues; what irritates the bull is really the matador's twitching of the cape, not its color.

The use of the names of colors in expressions ("seeing red," "once in a blue moon," or "a red-letter day," for example) actually has more to do with the fourth factor influencing our perception of color—the experiences and personality of the viewer, or the process of "feeling color."

Feeling Color

It's your first day on the new job—big promotion, nice new office. You're sitting there, reflecting for a moment on your accomplishments before digging into the new challenges ahead of you. Everything should be rosy, yet there's something bothering you. You can't quite put your finger on it until it hits you: It's the color scheme of your office. The oranges and aquas remind you of, well, of a Howard Johnson's restaurant. Suddenly, some of the glamor is gone.

Life would be dull if our brains merely registered the signals sent to them by the rods and cones through the optic nerve. Instead, our minds bring memory, imagination, and reason to the activity of sensing color. According to art historian Rene Huyghe, "from the moment the sensation comes into consciousness it is connected in time with what no longer exists except in memory. The sensation of color does not just affect our psychology at the time when it occurs, it connects with all of our experience in time."[5]

To look without preconceptions, then, is virtually impossible. Color is something we see, but we adjust what we see based on our experiences. Because our experiences occur within the context of the culture we live in, we develop symbolic ways of sensing color. These differ from culture to culture. For example, white is associated with death in Japan, while for most Westerners it immediately calls to mind purity.

Color and Object Become Cultural Symbol

Symbolic ways of sensing color are almost always tied to specific objects—white mourning clothes in Japan, white wedding dresses in the United States—which is why one color may have widely different connotations from one culture to another, or even within the same culture. To Americans, for example, black is a symbol of death, yet a chair upholstered in black leather suggests affluence and sophistication.

According to colorist and art educator Patricia Sloane, "Response to color symbolism is a response to color preconception, and is a predetermined response based on literary and psychological ideas about color, rather than a response to the nature of color itself. In part, man feels impelled to create symbols—and to impute symbolic connotations to color—because he cannot help allowing his feelings and emotions, his literary, psychological and intellectual preconceptions, from interfering with his direct perception of the physical world."[6] In other words, humans can't resist the urge to add to what they see how they think and feel about it.

Our human need to develop a symbology for colors—reflected in fashion, culture, and tradition—is matched by our need to experience the joy that sensing color brings. Scientists C. A. Padgham and J. E. Saunders believe that "our ability to see color is highly elaborate for the mere necessities of reproduction and survival. Our capability is far beyond what is needed for distinguishing ripe from unripe fruit or acuity for mobility. Joy in color is a bonus of our senses."[7]

Joy Through Color Absent from Offices

Unfortunately, allowing our brains to sense joy through color hasn't been a high priority in office environments. Often, companies become interested in color only when they think it will make their people work harder. So interiors may be red, orange, or yellow because these colors are said to stimulate and excite.

Others prefer a soothing environment because it supposedly allows workers to focus on their tasks. Soothing usually gets interpreted as bland—pale greens, light yellows, and off-whites. Research has shown, however, that these uses of color have only short-term effects. People in environments where few colors dominate—either bright or bland—come to dislike them. A light green, for example, chosen to soothe workers may begin to remind them of the bland green of hospitals and cause negative reactions.

The use of color to manipulate people in the workplace is giving way to an approach that recognizes that providing humans with aesthetic enjoyment is essential within built environments. Psychologists Stephen and Rachel Kaplan argue that "discussing the preferred environment, suggests the decorative rather than the essential, the favored as opposed to the necessary. But viewed within the larger evolutionary context, preference, even aesthetics for that matter, are closely tied to basic concerns. An organism must prefer those environments in which it is likely to thrive; likewise it must dislike environments in which it is likely to be ineffective or handicapped or harmed in any way. Preference in this context is to no small degree an expression of human needs."[8]

Selecting is a Critical Part of Seeing

Our need for the enjoyment that sensing color provides is always balanced by our tendency to select and bring order to what we see. As science writer Edmund Blair Bolles notes, "We shift from sensation to sensation, watching only part of the visual field, listening to only some sounds around us, savoring certain flavors amidst many. Our capacity to select and impart intensity to sensation prevents us from being slaves to the physical world around us."[9]

Gestalt psychologists describe our inclination to select and order what we see as the principle of figure-ground perception, or our tendency to regard any kind of pattern or form we see as a figure against a background. Most people need the psychological and physical moorings of a high figure-ground organization in order to make sense of their environments. They become disoriented in environments where figure-ground relationships aren't apparent, such as those in which carpet, furniture, and walls all have the same pattern or are the same color.

On the other hand, the tendency to see in figure-ground relationships means our brains often supply information that is missing from what we see. When we see a square table with three chairs around it, we automatically look for the fourth, sometimes supplying it in our minds even though it's not there. This is the principle of closure, our tendency to see incomplete patterns as complete or unified wholes. In a related way, we tend to see furniture of different styles but the same color as a unified group.

At the same time that our brains are sensing color on a conscious level, they are also responding to it with phenomena that operate so quickly and effortlessly they seem unconscious. These phenomena include color constancy, simultaneous contrast, optical mixture, and spatial dimension. Each has an impact on how our brains perceive color.

The Eye Compensates for Color Differences

The first of these, color constancy, involves our tendency to compensate for the effect of various light sources on the color of the objects we see. Say a company's logo is displayed prominently just outside its corporate headquarters building. Here, we see its color in daylight. Just inside the building, we see the logo again, this time illuminated by fluorescent lamps. That evening, we leave the building and see the outdoor logo illuminated by spotlights.

Without the proper filter for each viewing situation, a camera would register dramatic shifts in the logo's color because of the various light sources. Our brains, however, rapidly compensate for each situation, and we perceive the color of the logo as the same in all three cases. It's not that we don't perceive the differences; we do. It's just that we make allowances for them.

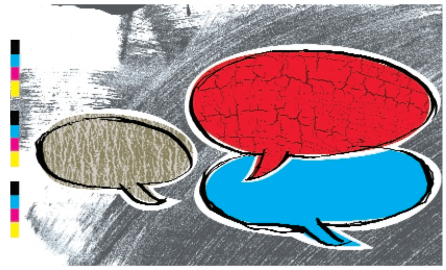
Our minds prefer the psychological equilibrium that results from accepting the logo colors as the same. By doing so, we free ourselves to focus on the differences we perceive in the environment that are of greater importance to us.

Scientists support this view. They use the example of our prehistoric ancestors learning to distinguish between ripe and unripe fruit to suggest how our color constancy function may have evolved. Because the angle of the sun's rays reflecting off the fruit high in a tree varied depending on the sun's location in the sky, the color of the fruit varied. Our ancestors' ability to distinguish ripe from unripe even though the color of each varied throughout the day slowly evolved. In other words, we learned to make allowances for slight color differences resulting from changes in the light source.

Mismatching Colors is a Different Problem

This psychological tendency to make allowances that are approximate has nothing to do with the physiological activity involved when we sometimes mismatch colors. You know about this if you've ever chosen two socks that matched under your incandescent lights at home only to find that one is taupe and the other grey when you get under the fluorescent lights at the office.

This phenomenon is called metamerism: Two pigment formulas appear to match under one light source but not under another. Suppose the



green paints (pigment formulas) used on files and flipper doors are supposed to match, but the paints haven't been matched under the light source that will be used in the office they'll be placed in. The result may be a very unattractive mismatch.

Mismatches occur because, as George Agoston, an engineer and an artist, explains, "One color response, for example a particular green, can be evoked by any one of a set of stimuli [the light that comes to the eye from the object] all of which have a different wavelength composition…If the wavelength composition of the illumination that falls on the matching paint films is changed (for example, from that of light from an incandescent lamp to that of light from a fluorescent lamp), then it is almost certain that stimuli that come from the two films will…be different; the match will no longer be good."[10]

We Perceive Colors Depending on What's Around Them

The second brain phenomenon that affects how we experience color —simultaneous contrast—involves our tendency to perceive colors differently depending on what is around them. Designers are well aware of how grey carpets seem to shift in color, depending on the surrounding wall color. This occurs because our perception of one color becomes tinged toward the complement (the color directly opposite another on a color wheel) of the color around it. For example, a grey square looks reddish on a green background and greenish on a red background.

When complementary colors of equal intensity are next to each other, the afterimages (the ghostly tinges of color we see when we look away) heighten our experience of both colors. That is why red/green or yellow/purple or orange/blue color combinations are the most startling. It is also why, when we study a painting, the afterimage of one patch of color influences the next patch of color we look at. The same thing happens when a worker stares up at a magenta flipper door and then looks down at a light-toned work surface, which appears to have a greenish cast.

Two Colors Can Mix and Appear Like a Third

The third brain activity that influences our perception of color—optical mixture—is the opposite of simultaneous contrast. When an object's patches of color are so small that they pass below the threshold of conscious perception, we see the colors as optically mixed. Sometimes, as when the two colors on a top spin too fast to be seen individually, we perceive a third color. This also happens when viewing a multi-colored brick building from a distance. The building appears to be one color, optically mixed.

Understanding optical mixture in interiors is necessary for determining where best to use patterns, especially in regard to their scale and location in a room. Choosing a colored pattern without evaluating it in the position it will occupy in a space can be risky. A tackboard covered in a fabric with a small pattern may look red and blue close up, but from a distance the red and blue will mix and the tackboard will look purple among the other red and blue elements in the space. That combination may not be what the designer intends at all, or it can be a way of achieving a new color without actually using it in the scheme.

Some Colors Make Objects Appear Closer

Spatial dimension, the fourth of these internal phenomena, occurs when our brains add or subtract distance, depending upon the colors perceived. We tend to perceive warm-colored objects—red, orange, and yellow—as closer than cool-colored ones—green, blue, and purple. This may have more to do with the focal point at which we see the colors than with their perceived "temperatures," however.

Red, orange, and yellow may be "warmer" in the sense that they are closer to us, since red has a longer wavelength and therefore a closer focal point than blue does. The shorter wavelength of blue and its longer focal point may mean "cool" as in "distant." The implications for interior spaces are obvious: If you want to make a space seem larger, you choose green, blue, or purple for the ceiling and walls because they appear to recede, giving the space a more open feeling.

Speaking Color

You're late for a meeting with the designer who is redoing your offices. On the way into the conference room, you pass a colleague who says the new colors are "gross." You enter the room and get a full presentation on a grey and mauve color scheme that looks really nice to you. Later, you ask your colleague about her comment and discover that "gross" actually meant "out of fashion."

If we could get inside each other's heads, communication about color would be more accurate. Since we can't, we must fall back on language to describe what we perceive. There are some, like Mary Buckley, an artist and educator, who believe this is a good thing. She says that "detecting and naming attributes is basic to developing an understanding of light and color."[11]

Language Describes Colors and Their Effect on Us

Indeterminate, or nonmeasurable, attributes, such as shocking pink and clear-sky blue, are more than just adjectives. They are terms we use to explain the effect a color has on us. They are the words we use to describe our state of mind as we experience colors. Buckley is among a growing number of colorists and designers who believe that naming the intent of a space through the use of indeterminate attributes must occur before any discussion of specific colors. Users should first respond to the question "What should the space feel like?" The subjective responses to this question will direct designers in their color choices.

Sometimes these indeterminate attributes verge on a synesthetic response: They use the language of one sense to describe the perception of another, as in loud pink and tart green. But perhaps the most interesting attributes we commonly use are warm (reds, oranges, and yellows) and cool (greens, blues, and purples). These divisions are deeply embedded in our thinking, as evidenced by the red faucet for hot water and the blue for cold found in most washrooms, even though the actual temperature of red light is cooler than that of blue light.

Manufacturing Required a Specialized Language of Color

With the advent of the Industrial Revolution, however, the focus shifted away from a reliance on language to communicate color. In order for manufacturers with plants scattered around the country to maintain color consistency in their products, they began searching for a new technology that would provide accurate color definition.

During the last half of the nineteenth century, several people developed more precise ways to describe specific colors. They based their work on three basic, universal, measurable characteristics of color: 1) which spectral category it belongs to; 2) how light or dark a color is; and 3) how brilliant or dull it is.

Color terms for these characteristics vary. Some use the distinctions warm/cool, light/dark, and brilliant/dull. Others speak of hue, value, and chroma. Hue is the basic name of a color, such as red, yellow, green, or blue. Value indicates how light or dark a color is. Chroma is the amount of hue in a color. For example, vermilion has a great deal of red but pink has very little.

Munsell's System describes color in three dimensions. The American art educator Albert Munsell (1858-1918) developed the widely used Munsell Color System, which arranges all colors on the basis of their appearance. He was the first to call the three main characteristics of color "hue," "value," and "chroma," likening them to a musical note's pitch, tone, and intensity.

Others, such as the German chemist Wilhelm Ostwald (1853-1932), developed color systems based on different scientific principles. But all color systems share one common feature—they all map the three characteristics of color in three dimensions on XYZ axes. According to Sloane, "Dimensions beyond these three exist, although we do not know how to incorporate a fourth or further spatial dimension into the model graphically. Colors, for example, can vary in shininess of surface. The Munsell System acknowledges this parameter but suggests no way to incorporate it into the three-dimensional color solid."[12]

CIE Standards Provide Ultimate Precision

In the 1920s, the scientists of the Commission Internationale d'Eclairage (CIE) developed a system for measuring the bands of color in light waves based on standards for daylight and artificial illumination. This precise measurement of the electromagnetic waves reflecting from the surface of an object allows furniture manufacturers, for example, to communicate precisely with fabric suppliers. When a manufacturer specifies the tri-stimulus values of 0.5375, 0.3402, and 0.2078, the supplier knows exactly what color is meant: cadmium red.

As exact as the CIE standards are, they are cumbersome to use. Most people prefer to use color maps, such as the one Munsell developed. Although not as precise as the CIE standards, they are much easier to use. Whatever their limitations, these color maps do enable us to communicate color to anyone anywhere who has the same map. That means, for example, that panels painted in the United States can match exactly those painted in England. However, most manufacturers use CIE standards to test samples to make sure the colors are exactly right.

Using Color

Back when you began designing this project, you decided to use reds and purples in the space. But as soon as you did, you heard your mother's voice saying, "You can't do that; they'll clash." Now the project is finished and the client loves it, calling the space "vibrant and inviting." You realize that, at least in this instance, Mother was wrong.

Ever since we began using color to adorn and decorate, we've hoped to find a set of rules that would tell us how to use color correctly. As Swedish researcher Lars Sivik notes, "There is not, nor will there ever be, any general results from research that will make it possible to say what color or colors should be used in any set of circumstances."[13]

Since scientists couldn't find rules for the use of color, others invented them. As Sloane says, "Well into the twentieth century, many seekers appeared to believe that the arts, especially music and the visual arts, could not be considered genuinely respectable unless laws could be found that explained them and defined their purposes. If color harmony and other forms of beauty could be shown to have a rational basis, the arts would be revealed as more than just aesthetic. They would assume a position among the verities, an expression of natural law."[14]

The "laws" that do exist usually take the form of color trends based on recent purchases and social changes. Thus, some predict the 1990s ecological attitude will manifest itself in the use of more natural colors. Others predict the luminous colors of video games will influence color use for the next generation. These attempts to develop formulas for color don't go away, because though we may find it difficult to describe why, we know that color affects us deeply.

New Research Focuses on our Internal Responses to Color

Environmental color research published in the last two decades from Sweden and the United States has focused on our internal, or affective, responses to color in the context of an environment. This research has yielded two general findings: First, it dispelled the color myths that developed from earlier research that had tested people's reactions to colors in isolation and had suggested that there were temporary physical changes evident in heart rate, blood pressure, brain waves, muscle tension, and respiration rate when people were exposed to red versus blue. This led to a variety of color myths: Red is arousing, blue is soothing, red increases aggressive behavior, and blue and green calm and pacify.

Second, researchers Acking and Kuller (1972), Lars Sivik (1970), and Byron Mikellides (1990) all found that chroma, or the saturation or strength of a color, has much more of an effect on us than hue. In other words, we perceive a strong red and a strong green as equally exciting, while we perceive dull colors, no matter what the hue, as calming.

These researchers also found that arousal was heightened by multiple hues in an environment and was maintained over time by change and fluctuations in hue. Findings from other studies indicate that we associate a space painted in light colors with an open feeling and one painted in dark colors with a closed feeling, that we equate higher social status with darker colors, and that we feel an environment increases in complexity with higher chromas (deeply saturated colors) and multiple hues (many colors).

Synthetic Colors Have Broadened our Choices

Studies confirm that color has a strong influence on our perception of the environment. Though these studies provide broad guidelines for the use of color, they offer no formulas for making color decisions. And decision-making has become decidedly more challenging.

Before the advent of synthetic colors in the twentieth century, nature restricted the colors we could choose from—materials such as wood and stone had their own colors, or else the colors we devised came from the available substances and resins found in nature. Thanks to today's synthetic colors, color choices have become virtually limitless—drywall requires paint, plastics are pigmented, composites are coated—so that, as designer Ezio Manzini says, "Surface quality is now determined for the most part independently of other formal and functional aspects."[15]

While the number of choices available can make choosing colors seem an overwhelming task, the opportunity it provides for variety in our environments can only improve the quality of our workplaces. As environmental designers Frank and Rudolf Mahnke explain, "Color variety is psychologically most beneficial. It is not just that one color is better than another for a specific purpose, that one may be considered psychologically exciting or another calming, but a variety of visual stimulation and change in atmosphere is required in establishing a sound milieu."[16]

Modeling Previews How Colors Will Shape a Space

The crucial element in creating a stimulating work environment is a feeling of togetherness, a focal point, within a variety of stimuli. To achieve this, it is no longer enough to arrive at results through trial and error in real environments. The difficulties in visualizing the outcome of the use of color and its effects require that we simulate the results through modeling—by studying colors under the final illuminant, by observing a pattern under the conditions in which it will appear in the actual environment, by testing how the colors chosen both unify the space and provide detail.

The environments that we prefer are likely to be those that permit involvement—and to be involving, a space must have some diversity and mystery. Without them, we experience monotony. As management consultant Fritz Steele says, "Drab colors, dull surroundings with no decorative elements . . . seem more certain to have a depressing effect on users' energy levels and willingness to take action. Making effective design decisions in shaping a work setting requires one to be able to combine the many individual elements—workplaces, furniture, layouts, traffic ways, colors, shared facilities, lighting—into larger wholes. One focus should be on a flow of experiences and influences on users, so that choices are made based on long- as well as short-term effects, and on the workings of the system as a whole as well as on the activities of individuals or small groups considered independently."[17]

Color selection must continue to be based on the function of the space and the needs of its users. Our role in creating involving spaces that enhance our well-being is to go beyond the search for formulas, to know the few rules that do exist about color and then to look for ways to creatively break them in order to achieve new levels of aesthetic enjoyment and work enhancement. As Sloane says, "The secret of great colorists may be an ability to look at colors without preconceptions, without concern for what was thought about color in the past." (18) Such a bold approach to color will undoubtedly bring more joy and interest to the workplace.

Glossary of Terms

Achromatic Color Color not possessing hue. Self-luminous achromatic colors range from dim to bright, and surface achromatic colors range from black to white.

Chroma The amount of hue in a color.

Color Constancy The approximate constancy in the perceived color of an object that occurs even though changing light sources alter the intensity and spectral characteristics of the light that stimulates our eyes.

Colorimetry The science of the measurement and analysis of color.

Complementary Colors Two colors that, when added together in suitable proportions, yield an achromatic color. When color samples are arranged in a circle according to the hue responses they elicit, complementary colors appear opposite each other. In general, yellow hues are complementary to blue hues, blue-green (cyan) to reds, and bluish reds (magentas) to greens.

Cones Cone-shaped cells in the human retina that operate at higher light levels—during the daytime or in a lighted room—and sense chromatic color, or hues.

Determinate Attributes Characteristics of color that can be measured by various instruments.

Dichromatism The condition of seeing, or being able to see, only two of the three fundamental colors, or two colors and their combinations.

Electromagnetic Spectrum The entire spectrum of radiant energy, which, in addition to visible light, includes radio and television waves, infrared rays, ultraviolet rays, x-rays, and gamma rays.

Eye-Brain Neurology The interaction between the receptors in our eyes and the occipital lobes in our brains by way of the optic nerve that creates color sensations.

Figure-Ground Perception Our tendency to regard any kind of pattern or form that we see as a figure against a background.

Fluorescent Lamp A tubular electric lamp coated on its inner surface with a fluorescent material (phosphor) and containing mercury vapor. When electrons from the lamp's cathode bombard the mercury vapor, it produces ultraviolet light that causes the phosphor to emit visible light.

Gestalt Psychology Psychology based on the theory that physical, psychological, and biological events occur not through the sum of separate elements, as sensations or reflexes, but rather through formed patterns of elements. These patterns occur as integrated units that function singly or in interrelation.

Hue The term applied to distinguish one color from another, i.e., a red hue or a blue hue.

Incandescent Lamp A lamp whose light is produced by the incandescence, or the glowing due to heat, of its filament.

Indeterminate Attributes Language used to describe the subjective characteristics of color, i.e., the words we use to describe our state of mind as we experience colors.

Metamerism A phenomenon that occurs when two pigment formulas appear to match under one light source but do not under another.

Monochromatism The condition of seeing, or being able to see, only one of the three fundamental colors. Monochromatism is also known as total color blindness.

Optical Mixture A phenomenon that occurs when an object's patches of color are so small or our distance from an object's patches of color is so great that they pass below the threshold of conscious perception. At this point, the colors optically "mix" and we perceive another color.

Optics The science concerned with light, how it is created and transmitted, and the effects it produces.

Photoreceptors A mechanism that detects radiation. Human visual receptors cannot distinguish the various wavelengths of light that comprise a color stimulus, nor can they quantify any aspect of energy in absolute terms. These activities are performed by colorimetric instruments called physical receptors.

Radiant Energy Light that is capable of serving as a color stimulus. Radiant energy is released in bundles, or quanta, which may be thought of as traveling in waves of different lengths and heights but at the same speed, about 186,000 miles per second in air.

Receptors The rods and cones that lie near the outer retina. They contain chemicals sensitive to light.

Rods Spindle-shaped cells that are found only outside the fovea of the retina. They are sensitive to small amounts of light and are most useful at night when there is practically no color vision.

Retina The rear two-thirds of the eyeball. It contains a vast number of rod and cone receptors and nerves that are important for initiating conscious color responses.

Spatial Dimension A phenomenon that occurs when our brains add or subtract distance depending upon the colors perceived.

Simultaneous Contrast Changes in either the lightness or hue of a target produced by its surround, or our tendency to perceive colors differently depending on what is around them. Thus, when we closely examine two colored objects or two areas of color on the same object together, the color of each will be influenced by the complementary of its neighbor.

Surface and Surround The spectral characteristics of objects, including how a surface reflects, absorbs, or transmits light, and how the colors and textures surrounding a surface influence its color.

Symbology The art of expression by symbols; also, the study or interpretation of symbols.

Synesthetic Response A subjective sensation or image of another sense than the one being stimulated, as in color hearing, when sounds seem to have characteristic colors.

Trichromats Humans see color with three types of reception systems (red/green-, yellow/blue-, black/white-producing) from three types of cone photoreceptors (red/blue/green-making). Therefore, humans are known as trichromats.

Tungsten Lamp An electric glow lamp with filaments of metallic tungsten. This type of lamp uses very low wattage.

Value An indication of how light or dark a color is.

The Experience of Color Facts

The human retina has approximately 120 million rods and 4 million cones.

About half our dreams are in color. The other half consists of black and white images with only one or two objects standing out in vivid colors.

The shortest wave light that ordinarily serves as a color stimulus has a wavelength of 380 nanometers, the longest wave a wavelength of 770 nanometers.

Visible Light Waves

Wavelength (in Nanometers)	**Color Sensation**
760 - 647	Red
647 - 585	Orange
585 - 575	Yellow
575 - 491	Green
491 - 424	Blue
424 - 380	Violet

Infants can distinguish hues within the first several weeks after birth.

Studies of Preference for Single Colors

Description of Observers	**Most Liked**	**Most Disliked**
1,000 Filipino children	Red	Yellow
1,200 Japanese children	Blue	Orange
2,500 American children	Blue	Yellow and Orange
4,000 Dutch children	Blue	Orange
500 Chinese high school students	White	Violet

According to studies in Poland and America, the habitual wearing of dark-colored clothes to the exclusion of other colors can signify the wearer's depression.

The Tie Rack Report asked over 1,000 British men to choose tie colors to suit several formal and informal situations. Red nearly tied with blue for first place when taking a woman out to dinner for the first time, but it fell to last when it came to meeting her parents.

We associate brightly colored foods with freshness and flavor, which is why, for example, nine-tenths of the 3,700 chemical compounds the English add to their mass marketed foods do nothing but improve their appearance.

In theory, a bag of M&M's Plain candies has 20% yellow, 10% orange, 20% red, 30% brown, 10% tan, and 10% green pieces. In practice it has 32% yellow, 25% orange, 18% red, 10% brown, 10% tan, and 5% green pieces.

The place where the optic nerve enters the eyeball and begins to spread out is a blind spot. Objects whose images fall on this spot are not sensed.

Camouflage is as old as nature itself, but the French coined the word to describe the scientific activity of concealing and deceiving developed during World War II.

Pupil comes from the Latin pupilla, meaning "a little doll." When Romans looked into one another's eyes, they saw a doll-like reflection of themselves.

Seasonal Affective Disorder (SAD), which leaves sufferers feeling depressed and listless during winter months, can be corrected by daily doses of light 20 times brighter than average indoor lighting.

Not all languages name all colors. Japanese only recently added a word for blue. In the past, aoi was an umbrella word that stood for the range of colors from green and blue to violet.

The ancients in Western civilization believed that blue had special powers to ward off evil. Baby boys, prized for the labor they could provide, were dressed in blue to protect them. Girls were dressed in pink because legend had it that girls were born inside pink roses.

Towels that are dyed in strong colors are often less absorbent than towels of pastel shades. To create strong colors, more molecules of dye must attach to each fiber, leaving less room for water molecules to be absorbed.

Tyrian purple was only for the great. Caesar and Augustus decreed that none but the Emperor might wear it. In Nero's day, even the selling of it was punishable by death.

The Welsh word glas refers to the color of mountain lakes, whether blue or green.

The word "hue" can be traced back through the Anglo-Saxon to a Sanskrit term signifying "complexion," "surface," "appearance," and even "beauty."

The sun is white. All of the blue and most of the green light in the sun's rays at sunset are scattered by particles in the atmosphere. Only the red and orange light reach us, making the sun appear to set in a golden flame.

Tweeds, a mail order company, develops names from nature for the colors of its clothes. Here's a sampling from its fall catalog: Henna (orange), Fresco (pink), Moon Dance (gold), Dragonfly (beige), Pigeon (blue), Drizzle (light grey), Moonlight (grey).

Some color names have become shorthand for human conditions: seeing red (anger), green with envy (covetousness), in the pink (healthfulness), yellow (cowardice), green around the gills (sickliness), feeling blue (sadness).

Once in a blue moon: atmospheric particles from a volcanic eruption or a forest fire may be of exactly the right size to scatter all light of low and medium energy, with the result that only the blue component of the sun's rays reflecting off the moon reaches us, resulting in what appears to be a blue moon.

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