

OakenDoor

The Psychology of Color

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Table of Contents

[Color](#)

[Absorption and Reflection](#)

[Your Eye's Perception](#)

[Color Models and Management](#)

[Additive Color](#)

[Subtractive Color](#)

[The Significance of Color](#)

[Physiological Reactions](#)

[The Symbolism of Color](#)

[Choosing Effective Color Schemes](#)

[Considering Color Blindness](#)

[Appendix A](#)



Color

One of the nagging questions on every (good) UX designer's mind today is, "What color choices should I make when putting together designs. There are the conservative-minded who stick to black text on a white background; this is a solid concept for delivering no-frills information in a usable manner. Remember the term usable when reading through the rest of this document; usability is key and everything else is secondary, but usability doesn't always equal minimalism. The more artistic-minded UX designers and many existing and potential clients looking to make their design implementations unique and memorable tend toward more robust color choices and layout. For complex design implementations that use varying levels of intricate programming (animation, Javascript, Java, Perl, etc.) that need to draw attention on a page full of color and still maintain the usability of finite elements, there must be distinguishing color choices.

What color is, how it is created, and how we as humans view it is a centuries-old debate that can, to this day, break down into a vehement religious argument. Socrates postulated that fire originating from the eye combined with an object's intrinsic whiteness to produce color. Isaac Newton explored the true relationship between color and light in the 17th century, demonstrating that color did not reside in objects themselves but was rather a product of light, and that white light could be reconstructed by combining all of the individual wavelengths in the visible light spectrum. These wavelengths corresponded to seven individual colors: red, orange, yellow, green, blue, indigo, and violet.

The visible light spectrum isolated by Newton in his experiments makes up a small portion of the electromagnetic spectrum that ranges from low frequency, long wavelength regions (such as radio waves) to high frequency, short wavelength regions (such as X-rays). In between infrared and ultraviolet waves resides the visible light spectrum that includes the range of waves from 700nm (red) to 400nm (violet). While Newton proved that these individual wavelengths produced white light when combined, in actuality only three visible wavelengths are necessary to reconstitute white light: red, green, and blue.

The modern scientific study of color harmony and the evocative properties of color yield information that influences the work of fine artists, designers, and advertising executives. This guide to color theory sheds light on some of the more enigmatic aspects of the effective use of color, and it illustrates techniques that you can use to reveal color harmonies and harness the power of color symbolism.

How humans perceive color depends on the interplay of three elements:

- The nature of light.

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- The reflective properties of an object.
 - The ways that our retina and visual cortex process light waves.

Regardless of what medium we work in (paint, print, or the digital illustration) our ability to effectively use color depends on these processes.

Absorption and Reflection

When light waves strike an object in nature, the object can transmit, absorb, or reflect various individual light waves. Depending on the nature of the object and its atomic structure, it might reflect green light while absorbing the other wavelengths. The retina and visual cortex process this reflected light to produce our perception of color.

When artists and designers reproduce color on canvas or paper, they mimic this process by using pigments that absorb certain light waves while reflecting others. For instance, to produce green, we use pigments that absorb red and blue wavelengths. This process forms the basis of the color models used in both painting and print media.

Your Eye's Perception

Our ability to process light waves, whether reflected off of an object or emitted from a light source, depends on the retina of the human eye and the visual cortex of the brain. The retina contains three receptors, or cones, that respond to certain light wave frequencies. Red cones respond to low frequency waves, green cones respond to middle frequency waves, and blue cones respond to high frequency waves. These cones are not binary but rather act as channels that transmit levels of stimulation to the visual cortex, which processes the sum of these signals to produce the perceived color.

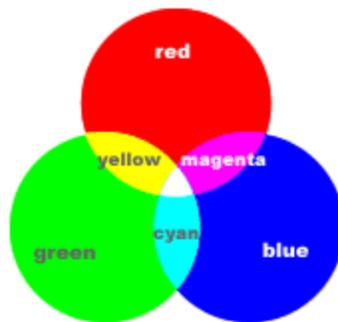
In order to produce the desired color, artists and designers must either add or subtract light waves, so that only certain light waves are reflected to the receptors. Whether you add or subtract light depends on the medium in which you are working.

Color Models and Management

When designers deal with color, they usually rely on one of two color models: the additive color model, in which individual color waves combine to form white light, or the subtractive color model, in which pigments are used to subtract light waves. Both the traditional artist's palette and the CMYK systems are subtractive color models. Where we deal with light projection rather than light reflecting off of objects, we use an additive color model called RGB.

Additive Color

In the natural world, the light waves that reach our retina are reflected off of objects, but there are other ways to produce color. Stage lights, for example, produce color by projecting white light through colored filters. Computer monitors also use projected light, but in that case the light is produced when electron guns are fired against a phosphor screen. These guns fire electrons in three colors: red, green, and blue. Using only these three colors, monitors can produce a full spectrum. This is known as the RGB color system.



Within the RGB system, designers can also produce a color spectrum by amalgamating these three primary colors. Combining two of the primary colors generates three secondary colors: cyan, magenta, and yellow. As previously noted, adding all three primary colors together produces white light. Thus, an RGB value of 255,255,255 produces white, as seen in the center of the previous graphic. The complete absence of the three primary colors (RGB: 0,0,0) produces black.

Subtractive Color

The inverse of the RGB model is the CMYK model, in which light waves are subtracted to produce the desired color. Since the color of an object is derived from reflected light waves, this system uses three primary colors that each absorbs red, green, or blue light. For instance, if you subtract red light, the remaining green and blue waves produce cyan. The pigment used to subtract red light and reflect green and blue appears cyan. Similarly, print designers use magenta to absorb a percentage of green light and yellow to absorb a percentage of blue light.

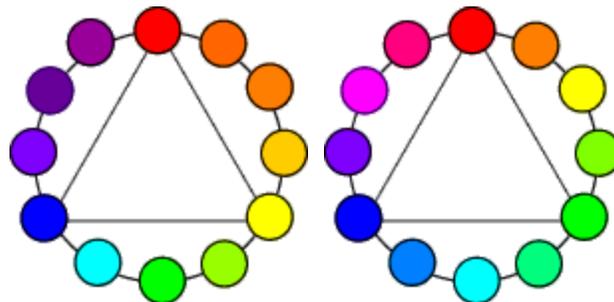
At this point, it should be apparent that the primary colors of the CMYK model are the secondary colors of the RGB model, and vice versa. Moreover, if red, green, and blue light combine to produce white light, it stands to reason that cyan, yellow, and magenta pigments should combine to create black, since they should absorb all of the light waves. However, due to the limitations of the pigments and the printing system, the full combination of cyan, yellow, and magenta doesn't

quite absorb all light. In practice, it's necessary to add black (the K in the CMYK model) to the system.

Color Harmony

One of the most challenging aspects of visual design is developing effective color harmonies that strike a balance between monotony and overstimulation. One place to begin exploring balanced and engaging color relationships is a color wheel--a representation of the hues available in a color model.

Each color model contains three primary colors from which all other colors are derived. In traditional color theory, the three primary colors are blue, red, and yellow. In the RGB color model, the primary colors are red, green, and blue. Any two primary colors combine to produce a secondary color. Tertiary colors are derived from either a combination of a primary and a secondary color or from a combination of two secondary colors. We use color wheels to present all of these colors in a logically arranged sequence. As you can see from the illustrations below, an RGB color wheel (right) differs significantly from the traditional artist's color wheel (left):



Color wheels expose relationships between colors that can be used to achieve both balance and contrast. The wheels include a number of full-intensity (saturated) hues as well as a variety of tints, tones, and shades, which are less saturated versions of the hue that include more white, gray, or black, respectively. While combinations of pure hues create dynamic color harmonies, you can design more subtle and subdued harmonies by using less saturated colors that are closer in value--that is, colors with similar degrees of lightness or darkness.

Some common color harmonies include:

<code>ccffcc</code> <code>99cc99</code> <code>669966</code> <code>336633</code>	Monochromatic: A monochromatic color set, as it sounds, uses a single hue but with varying tints and shades. Used correctly, this scheme can provide a nice, clean look.
<code>99ccff</code> <code>6699cc</code> <code>336699</code> <code>003366</code>	

<p>ffcc00 ff9900 ff0000</p> <p>ffcc66 cc6633 993333</p>	<p>Analogous: Colors that are side-by-side or very near each other on a color wheel. A grouping of three is shown to the left, but choosing four contiguous colors along the color wheel can also work well.</p>
<p>ff9900 cc6600 000099 0000cc</p> <p>ffcc99 cc9966 9999cc ccccff</p>	<p>Complementary: Colors appearing across from one another on a color wheel. These color combinations offer the maximum amount of contrast but can be overstimulating if used extensively. These are called complementary colors because, when used together, they seem to make each other brighter and more vivid</p>
<p>ffff00 993399 000099</p> <p>ffff99 cc99cc 666699</p>	<p>Split-complementary: One hue plus the two colors on either side of its complement. Split-complement harmony provides less contrast than straight complements.</p>
<p>006600 ff9933 660066</p> <p>669966 cc9966 990099</p>	<p>Triad: Three colors that are equidistant on a color wheel. This is the simplest approach to choosing colors. Simply imagine (or use) an equilateral triangle floating above a color wheel. Each color at the vertices is a usable color. In total, there are four possible triads that can be derived from the color wheel. See the color wheel in Appendix A. You can print it out (using a color printer of course) and begin drawing equilateral triangle points or vertices on the wheel. Repeat for each of the 4 possible triads.</p>

Now we're ready to start mixing things up a bit, what with the triads and the complementary colors and all. For example, you could combine two complementary pairs together, called a double complement. Something like yellow and purple, blue and orange. Another iteration of glorious color would be an alternate complement, where you combine a triad with the complement to one of the triadic hues. Green, reddish-purple, red, and orange for instance. You can also have a split complement that uses three colors, a hue and the two adjacent to its complement.



Finally, in the combination category, you can have a tetrad, an example of which is shown next, where you combine four colors that are directly across from each other. Here you would be using a primary, a secondary, and two tertiary colors.



99cc00	ffcc33	663399	0033cc	Tetrad: Two pairs of complementary colors.
cccc99	cc9933	660066	000099	

When exploring color harmonies, it's often useful to begin with pure hues, then experiment with various tints, tones, and shades. You can then test the visual effect of a particular color combination by using a wireframe diagram. Remember that the importance of contrast doesn't end with designing for impact; it can also help or hinder readability.

The Significance of Color

While examining the scientific nature of color and the aesthetic considerations of color harmony, we've seen that perception plays a large part in the effective use of color. Beyond the mechanics of perception and the recognition of balanced color palettes lies the intangible, visceral reaction that humans have to color. Colors evoke strong physiological and emotional responses both positive and negative. When you develop your color palette, make sure that the colors you select elicit the appropriate response.

Physiological Reactions

Although there has not been a great deal of conclusive evidence linking colors to specific responses, research suggests that certain colors do evoke physical responses. Red, for instance, is a very stimulating color and has been shown to produce increased heart and respiratory rates. Thus, red works as an excellent attention grabber and accent but could easily overstimulate when used as a background color. Similarly, yellow also demands attention, but since it is highly reflective, it creates eye fatigue and aggravation. On the other hand, the color blue has a relaxing effect on the nervous system, and some studies have shown that it increases productivity when used as a background color. However, don't use blue in your color scheme if your product is food-related, as blue is a natural appetite suppressant.



The Symbolism of Color

The symbolic meaning associated with colors sometimes has precedent in nature. For instance, the color of the sky or the sun creates certain fairly universal associations. However, the underlying meaning that we derive from most colors is based on cultural-specific elements—politics, religion, mythology, and other shared social structures—that may shift over time and across geographical boundaries. Be careful when designing and marketing sites specifically for audiences outside of your cultural reference, since a color that has a positive connotation in one culture may have a negative connotation in another. In addition, most colors have both positive and negative associations. You can emphasize certain meanings over others by using variations of value and saturation, or by using colors that combine two hues.

Common Color Connotations in Western Culture:

- Red: passion, romance, fire, violence, aggression. Red means stop or signals warning or forbidden actions in many cultures.
- Purple: creativity, mystery, royalty, mysticism, rarity. Purple is associated with death in some cultures.
- Blue: loyalty, security, conservatism, tranquility, coldness, sadness.
- Green: nature, fertility, growth, envy. In North American cultures, green means go, is associated with environmental awareness, and is often linked to fiscal matters.
- Yellow: brightness, illumination, illness, cowardice.
- Black: power, sophistication, contemporary style, death, morbidity, evil.
- White: purity, innocence, cleanliness, truth, peace, coldness, sterility. White is also the color of death in Chinese culture

Choosing Effective Color Schemes

Choosing the right colors for your site or application is a complex and often daunting task; many companies hire independent, special consultants just to devise color schemes that support and enhance an overall brand. However, if you have a sense of color harmony and understand the responses that certain colors can evoke, you can be your own color consultant and develop highly effective color combinations. Before you begin mixing and matching colors, you must first have a firm understanding of your site's message and goals. Once you understand what message you want to communicate, remember that perfecting a color palette is an iterative process, and



above all, a creative one. Don't be afraid to experiment with surprising color combinations, but be sure to adequately test the results before unveiling your product to the public.

Color Tips and Guidelines

1. Understand your site's message and brand. Choose colors that reinforce your message. For instance, if designing a site for a financial institution hoping to convey stability, choose cool, muted colors such as blue, gray, and green. In this case, using warm, vibrant hues would undermine the site's brand.
2. Understand your audience. Cultural differences can lead to unexpected responses to color. Additionally, demographic segments and age groups respond to colors differently. Younger audiences generally respond to more saturated hues that are less effective with older segments.
3. Use a small number of colors in your palette. Four or five colors, in addition to white and black, should be sufficient. Too many colors create discord and distract the user.
4. Use contrast for readability. Colors similar in value do not provide enough contrast and hinder legibility. Black text on white backgrounds provides the highest degree of contrast.
5. Use grayscale to test contrast. When dealing with hues other than black, white, and gray, it's sometimes difficult to determine the relative value of each color. To ensure that your color palette provides enough contrast, create a wireframe mockup and convert it to grayscale.
6. Be aware of timeliness when choosing colors. Color trends can quickly saturate the marketplace, and consumers rapidly become numb to fashionable hues. On the other hand, you can use popular color palettes from decades past to evoke feelings of nostalgia.
7. Consider functional colors when choosing a palette. Don't forget to establish functional colors for elements that communicate contextual information, such as headings and links.
8. Prepare for color differences. Designers and engineers should know that colors appear differently across platforms. Be sure to correct for gamma differences and test your color palette on multiple platforms.

Considering Color Blindness

Well, now that we've gone through an exhaustive and somewhat daunting lesson in color choices, I'm going to drop a real bomb on you. What about color-blindness? I know, I know; you're sitting there with your head in your hands saying, "oh, forget it, I'm going back to my job as a



nuclear physicist." Before you do that though, let's try to approach this issue of color blindness and see if we can't make some headway.

There are two basic kinds of color deficiency: anomalous trichromacy and dichromasy, as well as several categories within those two forms. A dichromatic person tends to have a more severe shifting or weakness, where an anomalously trichromatic person could have a wide range of color blindness. The differences between various forms of color blindness can be subtle and hard to diagnose.

An anomalously trichromatic person has either the red curve shifted toward the green range, or the green range shifted toward the red. These people are less sensitive to the color range that has shifted. An anomalously trichromatic person might see the green text as lime green, which would be quite hard to read. If the effect is subtle, an anomalously trichromatic person can see all the colors. It's just harder to tell them apart.

When a dichromatic person sees something green, both the red and green cones are activated, in addition to the shifting. Because red and green make yellow, green objects appear yellow. So if a site contains green text on a yellow background, both the text and the background appear yellow, making the text invisible. A dichromatic person with green cones shifted toward the red will also see the green as more yellow. This unpredictability makes simulating color blindness more difficult, and no doubt contributes to the difficulty in diagnosing the exact form of a person's color blindness.

Not only can most color-blind people see black and white accurately, but they also see all shades of yellow and blue. Most color-blind people can even see dimmer shades of yellow like gold and olive, for example.

Another trick is to keep colors bright. Bright colors are the easiest to tell apart. This is especially useful for those with a color weakness. They can see all the colors, but it's hard to tell them apart.

By placing colors against an appropriate background, you can make even less-safe colors visible. You can use red against white, green against black, turquoise against black, and magenta against black, although magenta does tend to appear lighter than it does for people who are not color blind. Also remember that even when using these colors against these backgrounds, something other than color should be used as an additional cue.

Considering that most color blind people have red-green color blindness, using red and green together is obviously a bad choice. Actually, red is most easily confused with a darker forest or racing green. With magenta and teal, appearances crisscross the spectrum from turquoise to pink and from orange to green. The grays in between get confused as well.



Another problem is the use of various shades of one color. Shades of turquoise all appear quite light, for example. This is why it's best to keep your colors bright and distinct.

Take into account that studies of color blind users revealed that a viewing problem is prevalent even among popular sites, and people are bothered by poor viewing ability even if the problem exists only on part of a page or site.

Web sites do exist for testing Web and application pages as well as page elements against the factor of color-blindness and vision deficiencies.

Here are some example sites:

<https://webaim.org/resources/contrastchecker/>

<https://www.color-blindness.com/coblis-color-blindness-simulator/>

<https://toolness.github.io/accessible-color-matrix/>

In conclusion, I think you will see that there are no easy answers, but hopefully this guide provides some starting points and metrics for making your color choices.

Appendix A

The usage of the following color wheel is detailed in the Color Harmony section of this guide to color.

