The following glossary lists and explains color and visual perception terms which are relevant for graphic and Web design as well as usability. The information was taken from several sources and adapted to the needs of this glossary. See References for more information.

In this version, some ISO definitions have been added.

**Accomodation**

**ISO Definition**: Adjustment of the focus of the eye, normally spontaneous, for the purpose of attaining maximum visual acuity at various distances. (Source: ISO 8995 (1989-10-00) ISO/TC 159)

**Achromatic Colors**

The "hueless" colors black, gray, and white, that is, the whole range of gray levels between black and white.

**ISO Definition**: Perceived colors devoid of hue. The color names white, gray and black are commonly used or, for transmitting objects, colorless and neutral. (Source: ISO 9241-8 (1997-10-00) ISO/TC 159)

**Figure**: Achromatic "colors".

**Adaptation (visual)**

**ISO Definition**: Process by which the state of the visual system is modified by previous and present exposure to stimuli that may have various luminances, spectral distributions and angular subtenses. (Source: ISO 9241-8 (1997-10-00) ISO/ TC 159)
Adaption

**ISO Definition:** The process which takes the luminance and/or the colour of the visual field or the final state of this process. (Source: ISO 8995 (1989-10-00) ISO/TC 159)

Additive Color

Synonym for the RGB (red, green, blue) color space that uses the projected red, green and blue light as primary colors to produce the full spectrum of colors. See also [Color Mixture -> Additive Color Mixture](#).

![Figure: The primaries of additive color mixing are red, green, and blue.](image)

Additive Color Mixture

See [Color Mixture -> Additive Color Mixture](#).

Afterimages

Afterimages result from localized adaptation of the photoreceptors in those parts of the retina exposed to the stimulus.

Monochrome Afterimages

If a black object on a white background (or vice versa) is being focused on for several seconds, and then a white area is being focused on, a negative afterimage is perceived. The afterimage may last for one to two minutes.
**Figure:** Monochrome afterimage - glare at the dots for several seconds and you will begin to see a negative afterimage, i.e. white dots

**Color Afterimages**

If a colored area is being focused on for a longer time (at least for about half a minute), and then a white area is being focused on, an afterimage of the complementary color is perceived. The afterimage may last for one to two minutes.

**Figure:** Color afterimage - gaze at the center of the image for about 30 seconds and then look away to a neutral area - an afterimage of the Union Jack will be seen.

-> Large areas of bright color should be avoided on screens because of the disturbing afterimages that can result.

**Aliasing**

Makes individual pixels visible, especially along diagonal lines and curves. Also known as staircasing or Jaggiess because of the steps that appear. Lines and text look more jagged than smooth.

**Figure:** Aliased (normal) lines (left) vs. anti-aliased (smoothed) lines (right)
See Anti-Aliasing.

**Anti-Aliasing**

A process that filters or softens the hard stair-stepped edge (and thus removes the [Jaggies](#)) in bitmapped images by creating a series of gradually blending pixels.

### Aliased Text vs. Anti-aliased Text

<table>
<thead>
<tr>
<th>Aliased Text</th>
<th>Anti-aliased Text</th>
</tr>
</thead>
</table>

See Aliasing.

**BMP**

See [Image File Formats](#).
**Brightness**

Brightness is the *perceived intensity* of light coming from the image itself, rather than any property of the portrayed scene. Brightness is sometimes defined as *perceived luminance*. (From Adelson, MIT)

**Brightness Assimilation**

Reverse effect of *brightness contrast*, seems to depend on cognitive factors like knowledge about the appearance of objects.

*Figure*: The gray under the white stripes appears lighter than the same gray under the black stripes due to brightness assimilation.

See also [Color Assimilation](#).

**Brightness Contrast**

See [Simultaneous Contrast](#) -> *Simultaneous Contrast (Black and White)*.

See also [Simultaneous Contrast](#) -> *Simultaneous Color Contrast*.

**Chroma**

Synonym for [Saturation](#).
**Chromatic Colors**

The "colorful" colors like, red, green, blue, yellow, purple, etc.

![Chromatic Primaries](image)

**Figure:** The chromatic primaries of additive color mixing are red, green and blue.

**Chromatic Induction**

Synonym for [Hue Induction](#).

**Chromostereooepsis**

Red and blue colors are perceived at different depths. This effect is due to the chromatic aberration of the eye (light of different wavelengths is refracted differently).

![Blue on Red and Red on Blue](image)

**Figure:** Foreground and background color combinations to avoid!

Because chromostereooepsis can be quite disturbing visually, avoid displaying both vivid red and blue together.

**CIE**

Commission Internationale de l'Eclairage - this commission determines standards for color and lighting. It developed the [Norm Color system](#) and the [Lab Color Space](#) (also called Lab Color System, or CIELAB Color System).

**CMYK**
See Color Space -> CMYK (see also RGB, HSL/HSV/HSB, Lab).

Figure: The primaries of the CMYK color space are cyan, magenta, yellow, and black

Color After Images

See After Images -> Color After Images.

Color Assimilation

Color assimilation (also known as the Von Bezold spreading effect or Bezold-Brücke effect) is the opposite of Color Contrast: Colors take on the hue of the surrounding color, whereas color contrasts moves it into the direction of the Complementary Color.

Example: The white squares on the red background in the figure below look reddish, and those on the blue background look bluish. Thus, the white squares tend to take on their background's colors.

Figure: The white central square shifts its hue into the direction of the surrounding color.

While the physiological mechanisms for brightness and color contrast phenomena are well understood, the conditions how and when the assimilation occurs are not. However, as with the brightness assimilation, the spatial frequency (coarseness) of the image seems to be an important factor.
The contrast and assimilation phenomena are also found for brightness and darkness (Brightness Contrast and Brightness Assimilation).

See also the Illusion Forum Website for animated demonstrations of many effects.

**Color Blindness**

See Color Deficiencies; see also Visual Impairments.
Newton's color circle is a convenient way to summarize the additive mixing properties of colors (see second figure below). R, G, B are thought of as the additive primary colors, and their complementary colors are placed across from them on the circle. The colors then fall on the circle in the order of the wavelengths of the corresponding spectral colors. Magenta (purple) is not a spectral color.

![Color Circle](image)

**Figure:** A color circle (from Apple Macintosh)

Saturation (purity of the color) can also be described by the color circle: colors become less pure or desaturated as you move into the center of the circle; colors become purer or saturated as you move towards the perimeter.

Quantifying the circumference of the circle in terms of *hue* and its radius in terms of saturation leads toward one of the formal color systems, the **Munsell System**. (Adapted from *Hyperphysics* Website)

**Saturation** (purity of the color) can also be described by the color circle: colors become less pure or desaturated as you move into the center of the circle; colors become purer or saturated as you move towards the perimeter.
**Color Constancy**

The human ability to maintain the percept of a particular *hue* throughout variations in the quality of the *luminance* or *reflectance* properties of the surface pigment. (Adapted from *Sensation and Perception*)

**Color Contrast**

See *Simultaneous Contrast* -> *Simultaneous Color Contrast*.

**Color Deficiencies**

Some individuals show drastic deficiencies in their ability to discriminate colored stimuli - these people are called colorblind, although this term is too strong for most of the deficiencies. According to the trichromatic color theory there are five types of color deficiencies to be distinguished:

- **Monochromats**
  - *Monochromats I*: people with no functioning cones; people with this deficiency have problems with daylight, because it is too bright for them; they also lack visual acuity
  - *Monochromats II*: people with only one variety of the cones functioning in addition to the rods; both types of monochromats see colors only as variations in intensity, that, is analog to black-and-white or unicolored images

- **Dichromats**: People with only one malfunctioning cone system
  - *Protanopia*: malfunctioning in the red cone system; typically only two (yellow, blue) or three colors (yellow, blue, purple) can be distinguished - yellow comprises red, orange, yellow, and green, blue coincides with blue and purple
  - *Deuteranopia*: malfunctioning in the green cone system; green cannot be distinguished from certain combinations of red and blue; this is the most common type of color deficiency
  - *Tritanopia*: malfunctioning of the blue cone system; longer wavelengths appear as red and the shorter ones as bluish-green; this color deficiency is very rare

Mild instances of color deficiencies are called "anomalous trichromatism" and are fairly common; typically these people do not act exactly like a dichromat, but need more red (protoanomaly) or green (deuteranomaly) than a color-normal individual to match colors. More than 8% of the male and about 0.04% of the female population have some sort of color anomaly or deficiency. (Adapted from *Sensation and Perception*)
**Figure:** Ishihara color blindness test charts (from *Allendale Eyecare Website*)

See also [www.visibone.com/colorblind](http://www.visibone.com/colorblind). Test your color vision at Michael Bennett's Website ([http://home.sc.rr.com/mikebennett/colorblind.html](http://home.sc.rr.com/mikebennett/colorblind.html)). Visicheck offers a color deficiency simulator ([http://www.vischeck.com](http://www.vischeck.com/))

For visual impairments in general, see *Visual Impairments*.

**Color Induction**

See *Hue Induction* (also called chromatic induction).

**Note:** The term *color induction* is used with different meanings.

**Color Mixture**

**Additive Color Mixture**

Additive color mixing describes how different wavelengths of light mix to make colors in the mind. This color mixing is explained through the combinations of the "primary" colors red, green, and blue (RGB). Color mixtures are usually demonstrated by shining overlapping beams of light through different color filters onto a white (colorless) surface (as in the diagram below), or by patches of pure colored paper or paint on a rapidly spinning disk (a "color top" or "Maxwell disk," so named because James Clerk Maxwell used it to study color mixing in around 1855, although it was first used for that purpose by Ignaz Shiffermüller in the 1760's).
Any color can be produced by adding the colors of the three color channels RGB (Red, Green, and Blue). If the colors of two of the color channels are mixed in equal proportions, new base colors are created. Blue and green add up to a bright, light blue called cyan. Magenta, a bright pink, is made by mixing red and blue. Red and green together make yellow. If red, green, and blue light are mixed equally together at full power, you get white light. (Adapted from www.linocolor.com)

Monitors

Monitors and televisions produce color by using electromagnetic waves that correspond to red, green and blue. However, screens aren't able to display the full range of colors which are visible to the human eye. Their range of color is limited. (From www.linocolor.com)

See also the Hyperphysics Website.

ISO Definition: Stimulation that combines on retina the actions of various color stimuli in such a manner that they cannot be perceived individually. (Source: ISO 9241-8 (1997-10-00) ISO/TC 159)
The opposite of additive color mixing, subtractive color mixing describes how the light absorbing properties of paints mix to make colors in reflected light. This color mixing is explained through combinations of the three subtractive "primary" colors cyan, yellow and magenta (CYM), and is usually demonstrated by placing multiple color filters over a single beam of light, or by physically mixing paints (i.e. inks or pigments that reflect light of a certain color). That is, the subtractive primary colors result when a section of the visible spectrum corresponding to a single additive primary color is absorbed from reflected white light. (Adapted from www.linocolor.com)

Figure: Mixing colors subtractively leads to a darker color (from www.mica.edu)

How Colors Are Printed

Printed colors differ from monitor colors in that they are produced by overlaying ink pigments on paper instead of by combining different wavelengths of light. If you tried to print red, green, and blue on top of one another, however, you could not produce many colors. You would not be able to make yellow, for instance. That is why printing uses subtractive instead of additive color mixing. (From www.linocolor.com)

Figure: Printing with RGB (from www.linocolor.com)  Figure: Printing with CMYK (from www.linocolor.com)

Why the K?

Theoretically, if we were to print a surface with equal parts of cyan, magenta and yellow, we would see black, because all colors would be absorbed and none reflected. In practice, however, this black looks more like a muddy green or brown. That is why four colors are generally used in printing ("four-color print"). Black (K) is used as the fourth color in order to achieve a real black. (From www.linocolor.com)
**Color Model**

System that describes colors for objective color production, as the Norm Color and CIELAB systems.

See Color Space.

**Color Space**

System that describes colors for objective color production, as the Norm Color and CIELAB systems; also called color model.

**The Color Space**

To integrate brightness into the picture, the color triangle must be transformed from a two-dimensional triangle into a spatial body known as color space. The color space is a three-dimensional system with coordinates for red, green and blue:

![Color Space Diagram](image)

**Figure**: The color space extends the color triangle into three dimensions

The further the color loci of the primary colors from the origin, the greater the volume of the cuboid color gamut which is formed and thus the higher the quality of any color reproduction system which is based on it.

All colors lying inside the color gamut can be reproduced by a reproduction system based on the primary colors (for example a color monitor). Colors outside the color space cannot be reproduced.

In other words: the primary colors of a color space are determined by the equipment which generates them. (From www.linocolor.com)

**RGB**
Color space based on the three primary colors red (R), blue (B) and green (G) used for additive color mixing. Televisions and computer monitors use RGB to reproduce color.

**Figure**: The three primaries of the RGB color space are red, green and blue

**CMYK**

Color space based on the three primary colors cyan (C), yellow (Y) and magenta (M) used for subtractive color mixing, plus the achromatic color black (K). The four process colors used in four-color printing.

**Figure**: The four primaries of the CMYK color space are cyan, magenta, yellow and black

**HSL, HSV, HSB**

Hue, Saturation, Luminance (also known as Hue, Saturation, Value or Hue, Saturation, Brightness): A system for describing the physical perception of color, in terms of tint (hue, color tone), perceived narrowness of the spectrum (saturation, chroma), and luminance (brightness, value).

Hue determines the position on the color wheel or color circle, Saturation is the purity of the color, and Luminance the range of lightness to darkness of the color.

**Application of the Model**

In the HSL color space it is easy to change hue, saturation and luminance alone without changing the other two characteristics; this is hard to achieve in the RGB color space that is offered by most graphic programs.

Hue can be changed by moving the position on the color circle:

**Figure**: Hue changes by moving the position on the color circle (from Hyperphysics)
**Saturation:** If, for example, blue is gradually added to a yellow, mixed from red and green, the yellow goes through steps of decreasing purity, each "less chromatic."

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**Figure:** Demonstration of adding blue in steps of 25% to yellow, represented as a mixture of 100% red and 100% blue

Colors of different saturation retain their original hue since the relationship between the color values of red and green are not changed. In the color triangle, they move along the straight connecting line from the yellow color locus towards blue, whereas in the color circle increasing saturation corresponds to a radial outward movement:

**Figure:** Saturation increases by moving outwards on the color circle (from *Hyperphysics*).

**Brightness**

If all three color components are reduced simultaneously -- while retaining their mixing ratio -- the hue remains unchanged. The color decreases in brightness. If the components of all three primary colors are reduced to zero, the resulting color will be black. Like white, black has a saturation level of zero.

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**Figure:** Demonstration of decreasing the brightness of pure blue in steps of 25%

See also [Lightness](#), [Luminance](#).
Norm Color System

In 1931 the CIE (Commission Internationale de l'Eclairage) developed the XYZ color system, also called the "norm color system." This system is often represented as a two-dimensional graphic which more or less corresponds to the shape of a sail.

The red components of a color are tallied along the x (horizontal) axis of the coordinate plane and the green components along the y (vertical) axis. In this way every color can be assigned a particular point on the coordinate plane. Colors on the left tend toward gray, which means that their spectral purity is decreased.

What is not taken into consideration in this graph is brightness (the z axis). If it were, the figure would look like a flat sack. (From www.linocolor.com)

Color spaces can be drawn for different devices (eyes, printer, screen) for comparisons.
**Figure:** Relative gamuts of additive (monitor display) and subtractive (printed) color; the larger area on the graph represents all visible colors. Click on the graph to see a more detailed version of the chart. (from *projectcool* Website)

See also [Color Triangle](#).

**CIELAB, Lab, L*a*b**

Color space defined by the CIE, based on one channel for Luminance (lightness) (L) and two color channels (a and b).

One problem with the XYZ color system, is that colorimetric distances between the individual colors do not correspond to perceived color differences. For example, in the figure above, a difference between green and greenish-yellow is relatively large, whereas the distance distinguishing blue and red is quite small. The CIE solved this problem in 1976 with the development of the three-dimensional Lab color space (or CIELAB color space).

In this model, the color differences which you perceive correspond to distances when measured colorimetrically. The a axis extends from green (-a) to red (+a) and the b axis from blue (-b) to yellow (+b). The brightness (L) increases from the bottom to the top of the three-dimensional model. (From www.linocolor.com)
This color space is better suited to many digital image manipulations than the RGB space, which is typically used in image editing programs. For example, the Lab space is useful for sharpening images and the removing artifacts in JPEG images or in images from digital cameras and scanners.

**Color Triangle**

Any three non-collinear points plotted on a chromaticity diagram determine a color triangle. Since the points are non-collinear, they correspond to basic, or primary hues. All of those colors on the chromaticity diagram which fall within the triangle determined by the three points may be produced by addition of the three hues.

Colors in the chromaticity triangle are defined by hue and saturation (chroma) only, not by brightness. There can be any amount of brightness in the chromaticity triangle.
All colors which can be produced by additive mixing of the three primary colors red, green and blue lie in the area enclosed by this color triangle. The further a color lies from the center of the triangle the higher its saturation (chroma). A mixed color has a high saturation level if it has only a small amount of its third component. A maximum saturation is found in colors mixed from only two primary colors.

If the amount of the third primary color is increased until all three primaries are present in equal components, white is the result - the saturation level is equal to zero, and the achromatic point lies in the middle of the color triangle (see color triangle above).

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**Figure:** Adding blue in steps of 25% to yellow, represented as a mixture of 100% red and 100% blue, eventually leads to white.

### Color Wheel

A color wheel arranges colors around the edges of a circle. Primary colors are in the middle. Three common color wheels are the artist's wheel, the subtractive wheel, and the additive wheel (see below). A standard color wheel has 12 distinct hues, but does not have any visual information about saturation or value. These 12 hues can be classified in:

- **Primary colors** - the defining colors of the wheel; in the color wheels below, they appear in the center as well as equally spaced around the circle
- **Secondary colors** - the three colors that are equal distant from the primary colors
- **Tertiary colors** - the colors between each primary and secondary color

#### The Artist's Color Wheel

This color wheel is used for mixing paints. It uses red, yellow, and blue as primary colors. Violet, green, and orange are secondary colors, and red-violet, blue-violet, blue-green, yellow-green, yellow-orange, and red-orange are tertiary colors.
**The Subtractive Color Wheel**

This color wheel uses the printing inks cyan, magenta, and yellow as primary colors.

*Note:* Because cyan (C), magenta (M), and yellow (Y) inks do not combine to make black, the printing process adds black as a fourth ink (K).

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**The Additive Color Wheel**

This color wheel displays the additive colors used for projected light. When mixed together the additive primaries form white. The primaries are red, green and blue. These colors are extremely bright because light that is projected can be far more intense than printed color.

(Adapted from projectcool Website)

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**Complementary Colors**

Colors that add to white when mixed adaptively. Complementary colors reside at opposite ends of the Color Circle or Color Wheel.

**Examples:** Magenta-green, blue-yellow, red-cyan
Complementary Colors - The Traditional Color Wheel
Complementary colors are those that are situated across from each other on the color wheel. There is a unity inherent in using complementary colors since any color has as its complement the sum of the other two primary colors. The complement of yellow, for instance is purple, made by mixing the other two primaries, red and blue. The complement of red is green, a combination of yellow and blue. Compositions created using complementary color schemes tend to feel complete and pleasing to the eye. Complementary colors will desaturate each other if mixed. (From www.mica.edu)

Complementary Colors - The Scientific Color Wheel
In the scientific color wheel, the symmetry or unity of the relationships of complements is even more evident. These six colors show both the pigment primaries of cyan, magenta and yellow along with the pigment secondaries of red, blue-violet and green. The complement of a primary pigment color turns out to be a primary light color. We could just as easily call this a color wheel for light (an additive wheel) with the primaries being red, blue-violet and green and secondaries of cyan, magenta and yellow. (From www.mica.edu)
**Constancies**

See Color Constancy and Size Constancy.

**Contrast Sensitivity**

The contrast sensitivity function for red and green is greatest for 10 point text (spatial frequency = 1 line pair/mm = 8 Hz/degree) at normal viewing distance (46 cm) and about 14 point text at arm length (65 cm).

For blue the greatest sensitivity is around a spatial frequency of 1 Hz/degree. The sensitivity itself is about one tenth of that of red and green. This is due to the scarcity of blue cones in the retina and to the absence of a local yellow-blue opponent mechanism. (From Jackson et al.)

**Figure:** The primaries blue, red and green in normal face and bold face on white and black backgrounds

**Cultural Variations in the Meaning of Colors**

**Overview**

<table>
<thead>
<tr>
<th>Culture</th>
<th>Red</th>
<th>Blue</th>
<th>Green</th>
<th>Yellow</th>
<th>White</th>
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<tr>
<td>USA, Europe</td>
<td>Danger</td>
<td>Manliness, sweet, calm, Authority</td>
<td>Safety, safe, sour</td>
<td>Caution, Cowardice</td>
<td>Purity</td>
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<td>Nobility</td>
<td>Freedom, Peace</td>
<td>Criminality</td>
<td>preliminary</td>
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<td>Virtue, Faith, Truth</td>
<td>Fertility, Strength</td>
<td>Happiness, Welfare or Wealth</td>
<td>Joy</td>
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<tr>
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<td>Life, Creativity</td>
<td>Welfare or Wealth, Fertility</td>
<td>Success</td>
<td>Death, Purity</td>
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<tr>
<td>Japan</td>
<td>Anger, Danger</td>
<td>Shame, Despicableness</td>
<td>Future, Youth, Energy</td>
<td>Grace, Dignity, Nobility, joyful</td>
<td>Death</td>
</tr>
</tbody>
</table>
(from different sources)

**Color Associations**

These associations are valid for western cultures only (see table above for differences). (from Jackson et al.)

The **Achromatics**

**White**

- **Positive**: Snow, Purity, Innocence, Peace, Lightness, Cleanliness
- **Negative**: Cold, Clinical, Vulnerability, Deathly pallor, Surrender, Sterility

**Black**

- **Positive**: Night, Coal, Power, Stability, Formality, Solidity
- **Negative**: Fear, Void, Death, Secrecy, Anonymity, Evil

**Gray**

- **Positive**: Intelligence, Maturity, Wealth, Dignity, Dedication, Restraint
- **Negative**: Confusion, Decay, Concrete, Shadow, Depression, Boredom

The **Chromatic Primaries**

**Red**

- **Positive**: Victory, Passion, Love, Strength, Energy, Sexuality
- **Negative**: Blood, War, Fire, Danger, Anger, Satan

**Yellow**

- **Positive**: Sun, Summer, Serenity, Gold, Harvest, Innovation
- **Negative**: Cowardice, Treason, Jealousy, Hazard, Illness, Folly

**Green**
Color Glossary A-C

- **Positive**: Vegetation, Nature, Spring, Fertility, Hope, Safety
- **Negative**: Decay, Inexperience, Envy, Greed, Escapism, Bad luck

**Blue**

- **Positive**: Sky, Sea, Spirituality, Stability, Peace, Unity
- **Negative**: Cold, Depression, Melancholy, Obscenity, Mystery, Conservatism

**Color Preferences**

Eysenck's "universal" order of colors for Western adults:

(1) Blue, (2) Red, (3) Green, (4) Purple, (5) Yellow, (6) Orange

**References**

Compiled and edited by Christine Wiegand and Gerd Waloszek (Product Design Center)

Source: [Color Glossary](http://www.sapdesignguild.org/resources/glossary_color/index1.html)
Color Glossary D-Z

[ABC]DEFGHIJKLMNOPQRSTUVWXYZ

Version 1.0, 03/18/2003

The following glossary lists and explains color and visual perception terms which are relevant for graphic and Web design as well as usability. The information was taken from several sources and adapted to the needs of this glossary. See References for more information.

In this version, some ISO definitions have been added.

Dither, Dithering

A process of placing different-colored pixels next to one another to create the illusion of additional colors. The eye sees the two adjacent colors, and the mind blends them into a third color. (From Looking Good in Color)
**Figure**: Original continuous tone photo for the demonstration of dithering (200% enlargement)

**Figure**: Dither pattern (left) and diffusing dithering (irregular pattern, right) for creating intermediate colors (200% enlargement)

**Figure-Ground Phenomenon**

The figure-ground phenomenon, also called figure-ground separation, refers to the human ability to separate figures or "foreground" information from a surrounding background or noise information. This phenomenon is often demonstrated with ambiguous images, where you can see only one of two possible interpretations of a scene at a time.
Figure: Different figures demonstrate the figure-ground or foreground-background phenomenon
Although there can be a number of perceptual attributes listed that distinguish figures from ground, we are still far away from fully understanding the stimulus factors and psychological processes that distinguish figures from ground. One of these is, for example, the smaller the stimulus the more likely it is seen as figure.

Figure-ground phenomena also lead to the perception of **subjective contours**.

**Foreground-Background**

See [Figure-Ground Phenomenon](#)

**Gamut**

The gamut is the set of possible colors within a color system. No one system can reproduce all possible colors in the spectrum. Thus, it is not possible to create every color in the spectrum with either additive or subtractive colors. Both systems can reproduce only a subset of all visible colors. While those subsets generally overlap, there are colors which can be reproduced with additive color and not with subtractive color and vise-versa. (©1998 ACM)

![Gamut Diagram](http://www.sapdesignguild.org/resources/glossary_color/index2.html)

**Figure**: Relative gamuts of additive (monitor display) and subtractive (printed) color; the larger area on the graph represents all visible colors. Click on the graph to see a more detailed version of the chart. (From *projectcool* Website)

The colors that can be created by each system are called a "gamut". The ACM diagram to the left, shows the relative gamuts of additive (monitor display) and subtractive (printed) color. The larger area on the graph represents all visible color. Click on the graph to see a more detailed version of the chart. (From *projectcool* Website)
**Gestalt Laws**

The Gestalt psychologists approached lightness perception, and perception generally, in a different manner from the Hering or the Helmholtz schools. They emphasized the importance of perceptual organization, much of it based on mechanisms that might be characterized as mid-level. The key concepts include *grouping, belongingness, good continuation, proximity.* (From Adelson, MIT)

![Figure](image)

**Figure:** Grouping by color (or gray level, left) and form (right)

See also the guest editorial in *Perception* 11/1997 (vol. 26)“[Colour in a larger perspective: the rebirth of Gestalt psychology](http://www.sapdesignguild.org/resources/glossary_color/index2.html)"

---

**GIF**

See [Image File Formats](http://www.sapdesignguild.org/resources/glossary_color/index2.html).

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**Halftone**

The process of converting a continuous-tone image into a series of one-color dots of varying sizes. The larger and closer together the dots, the darker the image. The finer and apart the dots, the lighter the image. (From lgc)
Figure: Continuous tone image (upper left) as it is possible on computer screens and a pure black and white version of the image.
created by a threshold process (upper right) in comparison to different halftone processes for printing: patterned dither (middle left), diffusion dither (mezzotint, middle right), dots at an angle of 45 degree (screened halftone, lower left) and the same image with a coarser dot pattern (lower right). Click the lower right image to see an even larger version and to see the computer simulation of the dots in detail.

HSL, HSV, HSB

See Color Space -> HSL/HSV/HSB (see also RGB, CMYK, Lab)

Hue

Hue, along with saturation and brightness make up the three distinct attributes of color (as defined in the HSL color space). The terms "red" and "blue" are primarily describing hue. Hue is related to wavelength for spectral colors (see Light). It is convenient to arrange the saturated hues around a Newton Color Circle. Starting from red and proceeding clockwise around the circle below to blue proceeds from long to shorter wavelengths. However, not all hues can be represented by spectral colors since there is no single wavelength of light which has the magenta hue - it may be produced by an equal mixture of red and blue.

There are many different mixtures of wavelengths which can produce the same perceived hue. The achromatic line from black to gray to white through the center of the circle represents light which has no hue.

Figure: The color wheel (left) shows spectral and non spectral hues; the color circle (right) also shows different levels of saturation

Hue Induction

Hue induction (chromatic induction, color induction) refers to the change of hue when colors are perceived
Hue Induction through Simultaneous Contrast

The target color seems to be tinged with the complementary color of the surround (most noticeable with a gray target).

**Note:** Hues in the red to blue range are most stable, i.e. are least affected by chromatic induction.

![Figure: Hue induction makes the gray look different.](image)

**Figure:** Depending of the color of the surrounding square the central neutral (gray) square gets a slight tint in the direction of the complementary color.

Hue Induction through Color Assimilation

When the areas of color in a pattern subtend very small angles to the observer (less than about a third of a degree), an effect opposite to simultaneous contrast occurs: Colors appear to become more like their neighbor instead of less like them.
Figure: The Bezold-Brücke effect (hue induction) makes the red (left) and green (right) assimilate their neighboring colors; see also an animated example

Consequences of hue induction:

- same colors appear to be different
- different colors appear to be the same

For more examples see Simultaneous Contrast -> Simultaneous Color Contrast.

Effect of Surrounding Color

Colorfulness of a target is also affected by the surround. In general colors look most colorful against another color in lower lightness, particularly gray.

Image File Formats

Below we list the mostly used image file formats, their characteristics, and uses.

BMP

Native bitmap file format (BMP = bitmap) for Microsoft Windows and OS/2 (slightly different). Files can be in 8-bit or 24-bit format and may utilize a lossless LZW compression.

Used throughout Microsoft Windows and OS/2 for bitmap files.

GIF

GIF = Graphic Interchange Format, 8-bit file format (or lesser bit depths, that is, 256 or less colors) developed specifically for the Internet by Compuserve. Offers automatic lossless compression (LZW, but best suited to horizontal patterns) and one transparency color.

Used for Web graphics which require only 256 or less colors, like graphics, text, screen dumps etc.
JPEG, JPG

24-bit file format with lossy compression. Offers variable degrees of compression: Higher compression rates result in smaller file sizes but also increase compression artifacts. Basically the compression is based on the reduction of the number of colors. When the image is compressed, colors may change slightly.

Used for Web graphics which require more than 256 colors, like photos, graphics with smooth gradations etc.

PICT

Native bitmap and object-oriented file format for the Apple Macintosh (comparable to WMF in Windows).

Used on the Apple Macintosh for bitmapped, vector-oriented and mixed files.

PNG

PNG = Portable Network Graphics, developed as a licence-free successor to the GIF file format. Offers 8 bit and 24 bit color depths, lossless compression and an 8-bit transparency mask for smooth transitions between foreground and background images.

Currently not widely supported and used on the Web.

TIFF, TIF

TIFF = Tagged Image File Format, platform independent bitmap file format (there are slight differences between Motorola-based systems (Apple Macintosh) and Intel-based systems (Microsoft Windows). Offers different bit depths, lossless LZW compression, alpha channels and more.

Used for exchanging images between different computer platforms.

WMF

Native bitmap and object-oriented file format for Microsoft Windows (comparable to PICT on the Apple Macintosh).

Used on Microsoft Windows for bitmapped, vector-oriented and mixed files (format of the clipboard).

Intensity

Light waves vary in intensity and wavelength (frequency). Intensity is proportional to the square of the amplitude of a light wave.
Jaggies

A term for "jagged" or stair-step effect found in enlarged bitmapped images. Anti-aliasing and higher resolution minimizes jaggies. (From Igc)

See also Aliasing and Anti-Aliasing.

JPEG, JPG

See Image File Formats.

Lab

See Color Space -> Lab (see also RGB, CMYK, HSL/HSV). See further CIE which introduced the Lab color system.

Lateral Inhibition

The combined effect of the summation of adjacent excitatory and inhibitory signals causes us to perceive an increased contrast at luminance boundaries (edges), but little or no contrast in uniform fields.

Figure: The Mach-band effect is caused by lateral inhibition
Figure: Simultaneous contrast (black and white) is also caused by lateral inhibition; it lets the same gray in the middle of the lager squares appear differently.

Light

Electromagnetic radiation emanating from light sources or reflected from non-radiating objects. Perceived by our eyes and processed in the brain.

- Physical dimensions: Frequency (wavelength), intensity (amplitude)
- Perceptual dimensions: Brightness - related to intensity; hue (tone, tint) - related to frequency (wavelength), lightness
- Psychological dimensions: warmness/coldness, moods induced by colors, color associations, cultural differences

The visible light spectrum lies between 380 nm (violet) and 760 NM (red).

Light travels at a constant velocity of 300,000 km/s; it takes 1.25 sec to the moon, and nearly 8 minutes to the sun.

Lightness

Lightness is the perceived reflectance of a surface. It represents the visual system's attempt to extract reflectance based on the luminances in the scene. (From Adelson, MIT)

ISO Definition: Brightness of an area judged relative to the brightness of a similary illuminated area that appears to be white or highly transmitting. (Source: ISO 9241-8 (1997-10-00) ISO/ TC 159)

See also Brightness, Intensity, Luminance.

Luminance

Luminance is the amount of visible light that comes to the eye from a surface.
Illuminance is the amount of light incident on a surface. Reflectance is the proportion of incident light that is reflected from a surface.

Luminance, illuminance, and reflectance, are physical quantities that can be measured by physical devices.

There are also two subjective variables:

- **Lightness** is the perceived reflectance of a surface. It represents the visual system's attempt to extract reflectance based on the luminances in the scene.
- **Brightness** is the perceived intensity of light coming from the image itself, rather than any property of the portrayed scene. Brightness is sometimes defined as perceived luminance.

(From Adelson, MIT)

**ISO Definition**: The physical measurement of the stimulus which produces the sensation of brightness, in terms of the luminous intensity in a given direction [epsilon] (usually towards the observer) per unit area of an emitting, transmitting or reflecting surface. It is the luminous intensity of the light emitted or reflected in a given direction from an element of the surface, divided by the area of the element projected in the same direction. Unit: candela per square metre (cd/m2)

**Note**: The luminance L, in candela per square metre, of a perfectly matt surface is given by the formula [see formula in the standard] where E is the illuminance, in lux; [rho] is the reflectance of the surface considered. (Source: ISO 8995 (1989-10-00) ISO/TC 159)

**Moiré**

Moiré is a repetitive box-like pattern that results when two screens overlap and are out of register. This effect occurs when scanning screened originals due to the overlapping influence of more than one screen - the scan screen of the scanner and the print screen of the original. Small stars or lines in the image make it appear as if it were made of fabric. (From [www.linocolor.com](http://www.linocolor.com) and lgc)
The Munsell color system is based on the HSL color space and is used for calibrating color systems. It matches colors to a set of standard samples (typically color charts), with adjacent samples based upon equal perceived differences in color. It divides hue into 100 equal divisions around a color circle. This is similar in approach to the Newton Color Circle except that the circle is distorted by assigning a unit of radial distance to each perceptible difference in saturation (called units of chroma). Since there are more perceptible differences for some hues, the figure will bulge outward to 18 values for some hues compared to only 10 for another. Perpendicular to the plane formed by hue and saturation is the brightness scale divided into a scale of "value" from 0 (black) to 10 (white). A point in the color space so defined is specified by hue, value, and chroma in the form H V/C. (Adapted from Hyperphysics)

Optical Illusion

Optical illusions define illusions in perception. They can be attributed to physiological (due to the
construction and functionality of the human eye) as well as psychological factors (due to misinterpretations while seizing and comprehending the perceived objects and situations). There are various types of optical illusions: Geometrical-optical illusions, illusions concerning motion, contrast, perspective etc.

See also "Goodie" Optical Illusions in the Resources section of the SAP Design Guild for detailed information.

**Parallax**

**ISO Definition:** Difference in the apparent relative positions of objects when viewed from different points
(Source: ISO/FDIS 9241-9 (1999-10-07) ISO/TC 159)

**Perception**

**ISO Definition:** Psychophysiological process occurring in the central nervous system, the product of which is knowledge about the environment. Perception is a dynamic process and is not determined merely by the parameters of the signals which initiated it. As a consequence, it is possible that the information obtained may be incomplete, uncertain, or incorrect. Knowledge may be based on one or more of the following levels of perception: detection, identification, and interpretation. Detection is the perceptual process by which the operator becomes aware of the mere presence of a signal. Identification is the perceptual process by which the detected signal is distinguished from other signals. Interpretation is the combination of perceptual and cognitive processes by which the contents and significance of the identified signal are recognised. (Source: EN 894-2 (1997-02-00) CEN/ TC 122)

**PICT**

See Image File Formats.

**Pixel**

**ISO Definition:** the smallest element that is capable of generating the full functionality of the display
(Source: prEN ISO 13406-2 (1997-07-00) ISO/TC 159)

**PNG**
See Image File Formats.

**Primary Colors**

Primary colors theoretically cannot be mixed from any other colors. The RGB primary additive colors (red, green, blue) can be mixed in varying combinations to produce millions of additive colors. The subtractive colors red, yellow and blue or magenta, yellow, cyan can be mixed as printer's ink or artist's pigment to produce thousands of colors.

Primary colors are: red, green, blue (additive color mixture), red, yellow, blue (arts, subtractive color mixture for paints) or cyan, magenta, yellow (subtractive color mixture for print).

**Note:** Often the colors cyan, magenta, yellow are called blue, red and yellow (like the primary colors for arts). Note however, that the secondary colors which are created by mixing the primaries are different if the first set or the second set is used. Be careful and consult the respective illustrations in order to not get confused by this ambiguity.

![Different triples of primary color](image)

**Process Colors**

A term that is a synonym for CYMK (cyan, yellow, magenta, black), the four inks used by printers to produce full-color printing. Also referred to as four-color printing.

![The four primaries of the CMYK color space](image)

**Psychological Effects of Colors**
Colors do not have only sensorial but also psychological effects and may affect people’s moods:

- **Cool**: blue, turquoise, violet
- **Warm**: yellow, orange, red, brown
- Achromatic colors (white, gray, black) may take on either a warm or a cool character with just a hint of color.
- Green and magenta are marginal, depending on which colors surround them - they will tend to the opposite.

Warm hues act stimulating, while cool hues act relaxing. These effects are, for example, taken into account when decorating the interior of buildings.

**Reflectance**

Reflectance (of a surface) is the proportion of incident light the surface reflects.

**ISO Definition**: The ratio of the luminous flux reflected from a surface on it. The reflectance depends on the direction of the incident light, except for matt surfaces, and on its spectral distribution. (Source: ISO 8995 (1989-10-00) ISO/TC 159)

**RGB**

See [Color Space -> RGB](http://www.sapdesignguild.org/resources/glossary_color/index2.html).

**Saturation**

Saturation is related to how much white content is in the stimulus - it describes the purity of colors.

As used in [HSL, HSV, or HSB](http://www.sapdesignguild.org/resources/glossary_color/index2.html) it refers to the presence or lack of chroma or color pigment. A color that is 100 percent saturated contains no white (monochromatic colors). A color that has 0 percent saturation is white.

**ISO Definition**: chromaticness, or colorfulness, of an area judged in proportion to its brightness (Source: ISO 9241-8 (1997-10-00) ISO/TC 159)
Secondary Colors

The three colors which are created by mixing the three primary colors. Additively mixing the primary colors red, green and blue results in the following secondary colors: cyan (blue-green), magenta (blue-red), yellow (green-red).

![Secondary Colors](http://www.sapdesignguild.org/resources/glossary_color/index2.html)

Depending on the primary colors, other secondary colors are created. For instance, the primaries red, yellow and blue, which are used in arts (pigments, thus subtractive color mixing), produce the secondaries green (blue-yellow), orange (red-yellow), and violet (red-blue).

Simultaneous Contrast

Simultaneous contrast is caused by lateral inhibition and can be observed for black-and-white as well as for colored images.

Simultaneous Contrast (Black and White)

Simultaneous contrast lets the central gray square look differently, depending on the surrounding gray level, although all the central squares are composed of the same gray.

![Simultaneous Contrast](http://www.sapdesignguild.org/resources/glossary_color/index2.html)
Simultaneous Color Contrast

Simultaneous color contrast effects that

- colors shift their hues into the direction of the complementary color (the opposite effect of Color Assimilation, where colors tend to adopt similar hues)
- colors look lighter or darker with respect to the background color (essentially the same effect as with black and white)

The change in appearance of a central area is caused by the presence of a neighboring area. The effect is strongest when the inducing field completely surrounds the target area.

**Figure:** Simultaneous contrast makes the central blue look different

**Figure:** Simultaneous contrast makes the central gray adopt different hues (and brightnesses, depending on the brightness of the surrounding color)
An Example

Color contrast and Color Assimilation or other effect of Hue Induction demonstrate that the perceived brightness/color of an object or region of a scene does not depend simply on its own brightness/color. There are basically two phenomena:

1. The same color may look differently
2. Different colors may lead to a similar color impression

Below are a few demonstrations of this, inspired by a book of Edward Tufte:

Figure: The same color looks differently depending on the surrounding color

Figure: Though the colors of the middle squares seem to look the same, they are different, as the next figure shows:
Figure: The colors of the central squares

Figure: This is how the same color (the left color) looks depending on the two backgrounds

See also Chromatic Induction, Hue Induction

Size Constancy

Size constancy denotes the stability of perceived size despite changes in objective distance and retinal image size.
Figure: Size constancy lets the person to the right appear much larger than the one to the left, even though both are of the same physical size (from Shepard)

**Stereopsis**

**ISO Definition:** Binocular, visual perception of depth or three dimensional space. (Source: ISO 9241-8 (1997-10-00) ISO/TC 159)

**Subjective Colors**

Colors which are perceived from moving, e.g. rotating, black-and-white images are called subjective colors. One such device is Benham's disk. It was invented by a nineteenth-century toymaker who noticed colors in a black-and-white pattern he had mounted on a top. Toy spinning tops with Benham's disks are still available in toy stores. The effects are, however, rather subtle.
Figure: Benham's disk for inducing subjective colors
**Subjective Contours**

Subjective contours demonstrate that form can emerge through the use of depth cues in a two-dimensional array - the observer perceptually "creates" the contours defining a form. Coren (1972) suggested that subjective contours arise when we use depth cues within a configuration to help organize an otherwise meaningless array into a simpler, more meaningful figure. A typical such depth cue is *interposition*, that is, the occlusion of an object by another one. The occluded object is perceived as the more distant one (see figures below). The figure defined by the subjective contour acts remarkably like a "real" contour even to the extent that it can mask a real contour. (Adapted from Sensation and Perception)
Subtractive Color

The opposite of additive color, subtractive color represents inks or pigments that reflect the light of a certain color. Its primaries are cyan, magenta and yellow. The primary colors of magenta, cyan and yellow can be mixed together to make up millions of colors. See CMYK and Color Mixture -> Subtractive Color Mixture.

Subtractive Color Mixture

See Color Mixture -> Subtractive Color Mixture.

TIFF, TIF
Visual Impairments

Most visual impairments have physiological reasons. Some of them originate from the lens alone, some from its physical relation to the eye ball, others from the sensors, that is from malfunctions of rods or cones, or the neural pathways and processing.

The tables below provide an overview of the most common visual impairments. For more information on visual impairments, see Vision and Visual Disabilities - An Introduction in the Editions section of the SAP Design Guild.

Overview of Visual Impairments

The first table covers impairments that are related to malfunctions of sensors. The second table includes impairments caused by defects in the optical or neural system or by diseases.

Sensor-Related Impairments

<table>
<thead>
<tr>
<th>Synonyms</th>
<th>Loss of Central Vision</th>
<th>Loss of Peripheral Vision</th>
<th>Low Acuity</th>
<th>Night-Blindness</th>
<th>Day-Blindness</th>
<th>Color Deficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tunnel vision</td>
<td></td>
<td>Glare sensitivity</td>
<td></td>
<td>Color blindness</td>
</tr>
<tr>
<td>Syllables</td>
<td>Cones</td>
<td>Rods</td>
<td>Cones</td>
<td>Rods</td>
<td>Cones</td>
<td>Cones (one or more types affected)</td>
</tr>
<tr>
<td>Syndromes</td>
<td>Macular degeneration (age-related or inherited)</td>
<td>Retinitis pigmentosa (RP)</td>
<td>Coincides with loss of central vision</td>
<td>Retinitis pigmentosa</td>
<td>Monochromats (all cone types affected)</td>
<td>Dichromats: Protanopia Deuteranopia Tritanopia Monochromats</td>
</tr>
<tr>
<td>Inverse retinitis pigmentosa</td>
<td>Usher syndrome (RP combined with hearing loss)</td>
<td>See also Glaucoma</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

See also Image File Formats.
Table 1: Overview of sensor-related visual impairments

<table>
<thead>
<tr>
<th>Synonyms</th>
<th>Sightnedness</th>
<th>Lens Clouding</th>
<th>Loss of Vision Field</th>
<th>Loss of Peripheral Vision</th>
<th>Focusing Problems, Distortions</th>
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</thead>
<tbody>
<tr>
<td>Remarks</td>
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<td></td>
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<tr>
<td>Affected Parts</td>
<td></td>
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<td></td>
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<tr>
<td>Syndromes</td>
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</table>

Typically remedied by glasses or contact lenses
Can be remedied by lens surgery
Can include total loss of vision
Can lead to total loss of vision
Can lead to total loss of vision

<table>
<thead>
<tr>
<th>Affected Parts</th>
<th>Lens, eye ball</th>
<th>Lens</th>
<th>Optic nerve (visual pathway), brain</th>
<th>Optic nerve (close to lens)</th>
<th>Blood vessels (arteries) in retina</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Syndromes</th>
<th>Farsightedness</th>
<th>Cataracts</th>
<th>Damages in the neural pathways or in brain regions dedicated to vision</th>
<th>Glaucoma</th>
<th>Diabetic retinopathy (caused by age-related diabetes)</th>
</tr>
</thead>
</table>

Table 2: Overview of further visual impairments

WMW

See Image File Formats.

References

Compiled and edited by Christine Wiegand and Gerd Waloszek (Product Design Center)