

Colour in Visualization

Colour Physics and Models

Tri-stimulus Theory of Colour Vision



Light falling on the retina is detected by rods and **cones**.

The three types of **cones** are sensitive to different wavelengths of light.



The tri-stimulus theory: different colours are perceived when different cones are stimulated by different amounts.

CIE Chromaticity Diagram.



All visible colours are represented on the CIE chromaticity diagram.

Pure spectral colours (single wavelength) are around the edge of the diagram.

The colours inside the diagram are perceived from more than one wavelength.

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CIE Chromaticity Diagram.



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It is often used to compare digital imaging devices against the capabilities of human vision.

The central triangle is all colours that can be represented by a CRT monitor its **gamut**.

The colour gamut is not identical for CRT & LCD. It is very different for printers.

RGB Colour Model

Additive colour model where colours are made up by combining proportions of three primary colours:

Red, Green and Blue

Used by emissive display, eg CRT, LCD.



© The Colour Group of Great Britain

Secondary colours are yellow, cyan and magenta.

RGB Colour Examples

All colours you see on current CRT & LCD displays are made of different proportions of red, green and blue eg:



The RGB components are often entered as integers in the range [0,255] as used by the graphics hardware. (Brown additive colour applet, colour mixing applet) Also represented in range [0.0, 1.0] or [0%, 100%].

Often known as **true colour** or **full colour** mode this can represent ~ 16 million different proportions of R, G and B. Not all visually unique however, there are **metamers**.

RGB Colour: Disadvantages

RGB is a device level colour model in that it relates to the graphics hardware and display system.

It can be (very) difficult to guess which combination of RGB values creates a specific colour.

There are several alternatives:

The colour naming system is good as each colour is given a name but not so good for adjusting colours.

There are several three variable alternatives that are easier to use than RGB, for example HLS and HSL.

HLS Colour Model

The hue, lightness and saturation colour model allows selection of colours with a more intuitive control.

- Hue is colour or shade.
- Lightness is closeness to white or black.



Saturation is vividness or depth of colour.



© Adobe systems

Note, for Paint Shop Pro users HSL is slightly different. Both HLS and HSL are also related to the HSV model.

CMYK Colour Model

CMYK is a subtractive colour model used in printing, light is absorbed by printed ink to create the perceived colours.

Magenta absorbs green light



CMYK comparison with RGB

CMYK and RGB overlaid on the CIE colour space.

Both colour models are unable to reproduce all visible colours.

In addition they do not fully cover each other's gamut.



Most electronic and printed images will not look the same, don't assume screen graphics will print out well – always test.

Get it right in black and white



Someone, one day, will print out your visualizations in black and white.

Check that, at least, the vital information still works.

What colours are there?

Color names if you're a girl...



Color names if you're a guy...

Doghouse Diaries

xkcd: a large survey of colour names



Names from an online survey of 222,500 people.

There is relatively little difference, women tend to add more qualifiers, and know the difference between aqua and teal.



The saturated RGB colour space divided by names given in the survey.

Most distinct 48 colours in the survey



There is a case these could be the most reliably identifiable colours.

There is a full table of the top 954 colours on the survey page:

Fuchsia

EveryoneWomenMenColorblindCRTfusciaImage: Second Second

No one can spell it – though many can see it

Choosing a colour palette

How many colours can we use?



Ware, Information Visualization for Design

Studies show there are only about 6-12 very distinct colours.

Red, green, yellow, blue, pink, brown, orange, grey, purple, plus black and white.

Good for nominal data but .. are these aesthetically or technically good choices?

Sequential colour palettes

L varies L and S vary H, L and S vary

Zellis et al, 2009

You can vary one or more of the HLS components to get a sequential palette, good for quantitative data.

PowerBI sequential palettes





PowerBI lets you set a colour palette of you add a value field to Color saturation. You can set the colours on the format tab, as well as give specific values for max & min.

Diverging colour palettes



Zellis et al, 2009

These have a neutral value in the middle of the palette and diverge in each direction, good for quantitative data.

PowerBI diverging palettes





By default PowerBI creates a rainbow colour pallete.

It is widely understood this is not a good palette for representing continuous values.

Equal perceptual steps in this palette are not equal numerical steps on a linear scale.

PowerBI Report Themes



Report themes allow you to customize almost every aspect of a report that can be set in the Format tab. The theme is stored as a text editable JSON file.

Predefined themes are available and there is a community gallery of themes you can download: https://community.powerbi.com/t5/Themes-Gallery/bd-p/ThemesGallery

In addition conditional formatting allows you to customize to your data when displayed in tables and matrices.

The Which Blair Project Rogowitz & Kalvin, IBM

"Color scales that did not include a monotonically-increasing luminance component produced no positive rating scores."



Figure 5 (b): The 8 overlapping HSV Decreasing Saturation scales (top), applied to the Blair photograph (bottom).

Perceptually Uniform Colour Maps Peter Kovesi, CET, UWA

https://arxiv.org/abs/1509.03700



Perceptually Uniform Colourmaps





https://peterkovesi.com/projects/colourmaps/

Color brewer

1. Sequential schemes are suited to ordered data that progress from low to high. Lightness steps dominate the look of these schemes, with light colors for low data values to dark colors for high data values.

2. Diverging schemes put equal emphasis on mid-range critical values and extremes at both ends of the data range. The critical class or break in the middle of the legend is emphasized with light colors and low and high extremes are emphasized with dark colors that have contrasting hues. Learn more »

3. Qualitative schemes do not imply magnitude differences between legend classes, and hues are used to create the primary visual differences between classes. Qualitative schemes are best suited to representing nominal or categorical data. Learn more »



Percent of population under 18 by state



Race or ethnicity



Colour blindness



There are a range of colour deficiencies in the population.

It is rare to be completely colour blind, but do check colours.

Try and be sure colour is not your only method for conveying information, e.g. use shape too, as below.



Summary of Colour

It is often easier to use the HLS model than physical RGB.

Remember different devices *cannot* show the same colours.

There are a limited number of distinct nameable colours.

Quantitative data - use sequential or diverging schemes.

Nominal/Categorical data - use qualitative schemes.

Design for colour-blindness and printability in black and white.

