

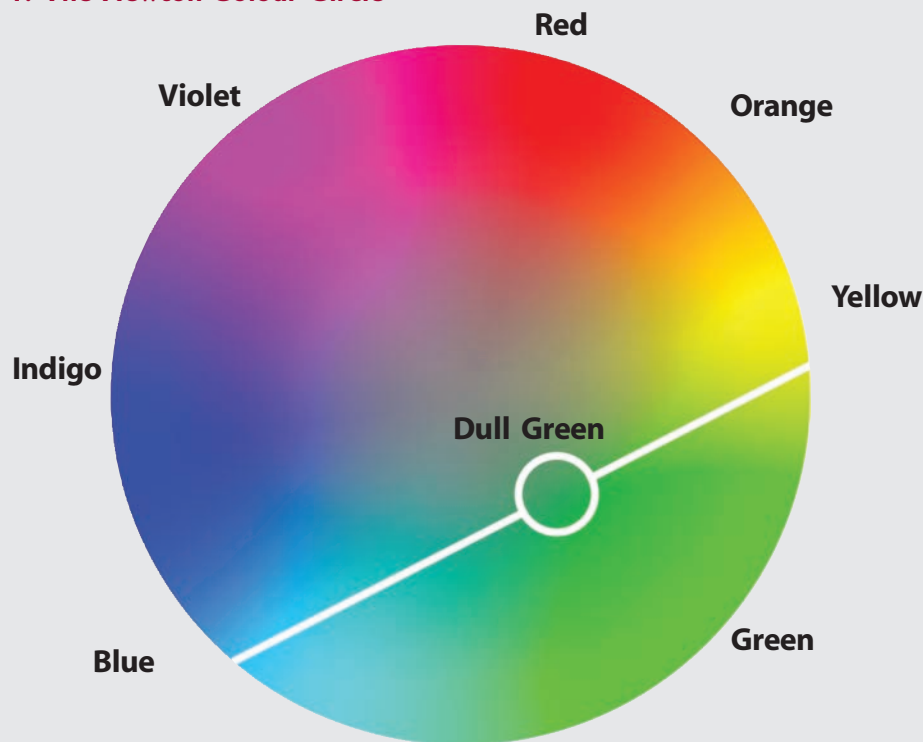


Colour Communication

Dr. Alois G. Püntener,

VESLIC (Association of Swiss Leather Chemists and Technologists)

Panel 1: The Newton Colour Circle



Isaac Newton made a study of colour starting at the age of 23 in 1666 and developed the Newton colour circle, published in his book *Opticks* in 1704. He developed the first scientific and practically appropriate colour space as presented in *Panel 1*.

Newton divided the spectrum (Latin for “appearance” or “apparition”) into seven elementary colours: red, orange, yellow, green, blue, indigo, and violet, placed on the boundary of a circle. A line between these seven colours should allow prediction about their mixture e.g. the line between yellow and blue gives a green, which is duller than the spectral colour on the boundary. Later his colour circle was criticised and suggested that indigo should not be regarded as a colour in its own but as a shade of blue or violet. Nevertheless, further important improvements in colour communication had to wait until the 20th century. In 1905, Albert H. Munsell illustrated the colours in a three dimensional space and his atlas is still in use today.

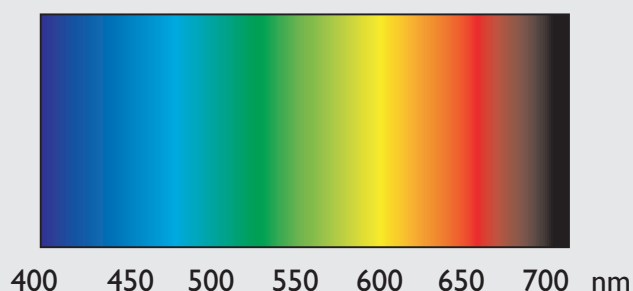
Colour perception

Colour perception is a sensation, caused by electromagnetic radiation striking the eye. The brain then experiences a sensation of colour by a complicated biological process. In a nutshell, five elements are necessary for colour determination:

- Light, because without light everything appears black
- The object which reflects e.g. leather
- The reflected light which stimulates the eye
- The brain then creates a sensation of colour
- Words to express colours, e.g. red, pink, deep green, etc.

Panel 2: Colour Spectrum

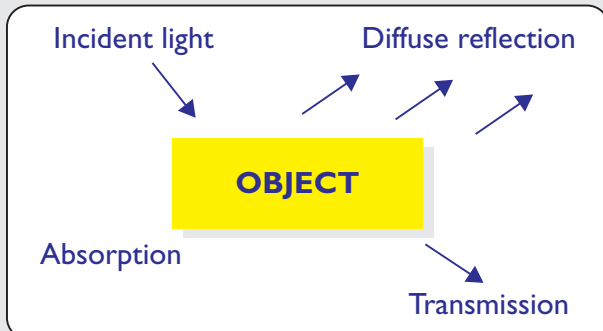
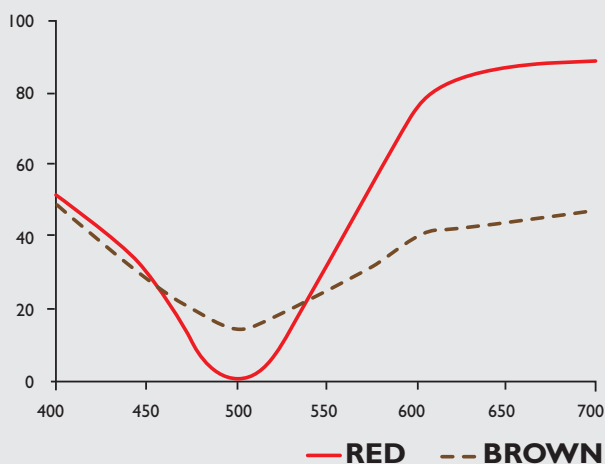
Visible radiation



The colours of the individual visible waves are known as spectral colours, and are presented in *Panel 2*.

When light strikes leather, part of the radiation is absorbed and the remainder is reflected. Transmission can be neglected. Here the impression of colour is created by the diffusely reflected radiation known as reflectance as indicated in *Panel 3*.

The reflection curves show which light is reflected. An object that diffusely reflects all visible light appears white, and the maximum reflectance is then 100%. If all the radiation is absorbed, the object appears black, and the reflectance is then zero. Red and brown dyed leather reflection curves are shown in *Panel 4*.

**Panel 3: How we see colour****Diffusion, absorption, transmission****Panel 4: Reflection curve of a red and brown leather****Reflectance**

As a rule, the steeper the reflection curve, the more brightly coloured the dye. The curves show that the red dye with the steep reflection maximum must be much brighter than the brown dye with its broad reflection maximum.

Systematic reflection, which requires a smooth surface, occurs with a mirror. It is also known in connection with leather. The leather surface, which appears rough to light rays, can be partially smoothed by suitable finishing producing the effect known as gloss. Care must be taken not to confuse this effect with the brightness of a dye. Gloss makes colours more brilliant, not brighter, and is not discussed in this paper.

Colour measurement

Light of a given colour entering the eye stimulates different centres. The world of colour is said to be three-dimensional, involving trichromatic vision. This means that besides recognising a shade we also have light/dark perception and a perception of dullness or brightness. Hence we can measure colour numerically by creating scales for lightness (dark/light)

hue (colour) and chroma (vividness).

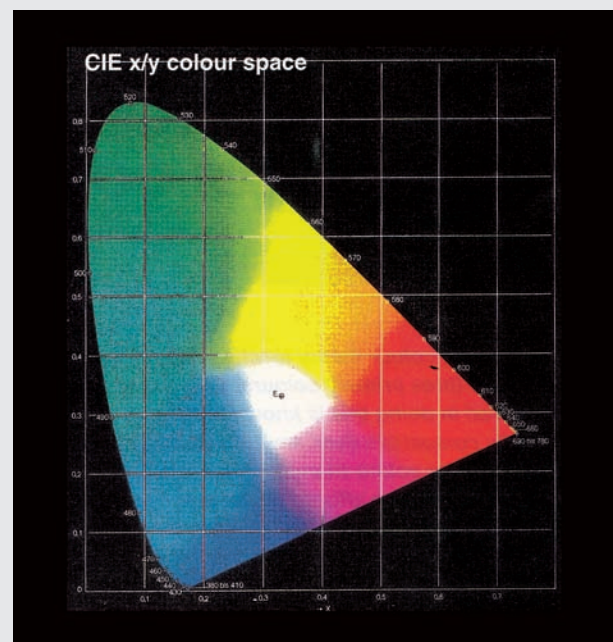
One of the first mathematically defined colour spaces is the CIE 1931 XYZ (or Yxy) colour space, created by the International Commission on Illumination in 1931. CIE is short for "Commission Internationale de l'Eclairage", which in English is the "International Commission on Illumination".

The colour point is illustrated on a graph, with the value of hue and chroma as cartesian coordinates on the horizontal axis and lightness at right angles to them. If the coordinates for all spectral colours are calculated and the resulting points plotted, we can immediately see that the pure spectral colours are obtained on the outside of the base surface.

On the straight line linking the end-points of the primary colours blue and red, lie mixtures of these primary pairs. Inside these lines (triangle) are the mixtures of all spectral colours with the achromatic point E in the centre.

Through this point passes the achromatic perpendicular Y with the value 0 = black 50 = grey and 100 = white. The Y value indicates the reflectance.

The colour space tapers towards the top and within this "pyramid" lie all the colours known to us. The CIE chromaticity diagram has been created to illustrate this. The pyramid viewed from above is shown as the Cartesian diagram with the x/y axes in *Panel 5*:

Panel 5: Yxy colour space (CIE 1931)**Colour identification and colour differences**

Today, the CIELab colour space is most popular for measuring colour. It is the abbreviation for the CIE 1976 (L^* , a^* , b^*) colour space.

The three parameters Y^* (Lightness), x^* and y^* (axes) as definition in the Yxy colour space were transformed into L^* , a^* and b^* to facilitate still better characterisation of colour and colour differences. If we plot the colour in $L^*a^*b^*$ values we see the colour space in the form of a "ball" instead of a "pyramid" and this is shown in *Panel 6*.



Panel 6: Representation of the CIE Lab colour ball



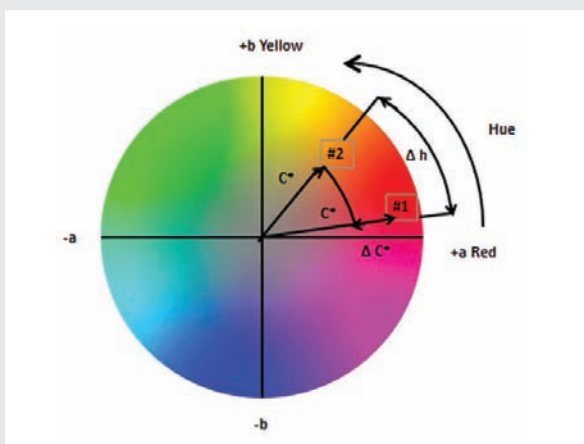
Panel 7: Calculation of the colour differences between the specimen and target colour

ΔE^* = colour difference

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

(Δ = difference with respect to reference)

Panel 8: LCh Colour difference



White is again at the top and black at the bottom and all spectral colours on the outside of the horizontal section through the middle of the ball. L^* is still the lightness or black-white axis (Value 0-100), a^* is the green-red axis (Value -60 to +60), and b^* is the blue-yellow (Value -60 to +60).

In practice, the value of a blue leather could be described

metrically as $L = 55$, $a = -8$ and $b = -50$ and a red leather as $L = 48$, $a = +45$, $b = +10$.

The colour value and the difference between two colours are of interest in colour matching. It allows people to quantify a notion that would otherwise be described with adjectives. The colour difference formula uses the CIE Lab system which permits calculation of the colour differences ΔE , and is set down in Panel 7.

Δ (delta) is a Greek letter used to denote difference, and E stands for "Empfindung", German for "sensation". ΔE values higher than 0.5 can be perceived by the trained human eye.

The Cartesian coordinates are further transformed into cylindrical coordinates $L^*C^*h^*$, known as CIE LCh colour space, which is the most convenient for practical use. The advantage is that the colouristic definitions are matched in terms of classification of the colour as hue (h) and the vividness as chroma (C^*). Lightness (L^*) remains the same as in the CIE Lab colour space. Chroma (C^*) is calculated from the distance of the colour point to the L^* axis and the hue (h) angle is measured anticlockwise from the $+a^*$ red axis towards the colour, as shown in Panel 8.

In this figure we see the section through the colour "cylinder". With reference to Panel 4 the brown dyed leather # 2 is duller (lower C^*) and more yellowish (higher h angle value) than the red dyed leather #1. The L^* value is not shown.

With the ability to define colour in a precise numerical manner, computers can be used to measure and compare colours. Also, by reading the reflectance curve of one coloured or pigmented leather and comparing this with the curves for known reference dyes or pigments, it is possible to calculate recipes to recreate a reflectance curve as close as possible to the original that is to match the shade.

In addition, we have to be aware that in 1994 the CIE refined their definition of colour difference, adding some small corrections forming CIE94 and later CIEDE2000. Also supplementary colour spaces are used in the industries and science, such as the Hunter Lab Colour Space or the CIE Luv space in order to meet specific requirements.

Metamerism

The term metamerism is used to describe the phenomenon observed when a matching pair of coloured surfaces under one set of viewing conditions changes to a mismatch under a differing set of viewing conditions. There are four main manifestations of metamerism depending on whether a mismatch can be brought about by changing:

- The observer
- The surface reflection
- Field-size
- The light source

Observer metameric failure occurs when, in a given set of viewing conditions, a colour match made by one observer is not confirmed by another. This obviously can cause serious problems if the two people are suppliers and customers. It is due to a difference between the eyesight of the two observers and is most marked when one has normal colour vision and the other suffers from some form of defective colour vision. It



also occurs where, due to age differences, the observers could have different degrees of yellowing of the cornea.

Geometric metamerism results from a change in surface reflectance when the arrangement of the light source, the observer and the object are altered. The most usual examples of this are noted with suedes and nubucks or when velvet textiles are used as patterns.

Field-size metameric failure occurs because colours that match when viewed as very small centrally fixated areas, then appear different when presented as large colour areas.

The term illuminate metameric failure describes the most common and important form of metamerism, where two material samples match when viewed under one light source but not another.

We know that daylight will vary according to the degree that sunlight is scattered and absorbed. We have to consider:

- Latitude of the place of measurement
- The season of the year
- Local weather conditions
- Time of day
- Environmental pollution in the air

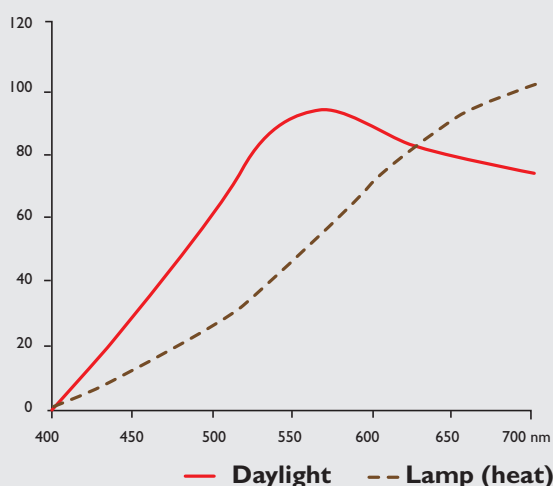
In the past, professional dyers and colourists in central Europe had preferred to utilise for shade norm comparison daylight with a grey overcast sky between 10-11am and 14-15pm. Artificial light may be consistent but has a different spectral distribution.

Artificial light is produced in two major ways. Initially, light can result by heating matter to such an extent that their materials emit radiation. This produces a continuous spectrum over a certain range. Alternatively light can be produced through an electrical discharge obtaining line spectra. An example of differences between daylight and artificial light can be seen in *Panel 9*:

Panel 9: An example of spectral distribution of daylight and indoor light

Spectral distribution

Relative energy



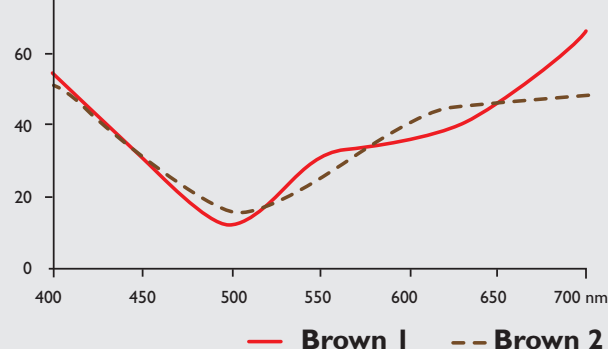
The CIE is the body responsible for publishing the entire well-known standard illuminates, which is the source of visible light with a published profile (its spectral distribution). Standard illuminants provide a basis for comparing colours recorded under different lighting. The best-known measure of metamerism is the distance between the test and reference spectral reflectance vectors in the CIE 1964 colour space.

The most usual changes giving rise to metamerism is the move from daylight to artificial light. As a case in point, the energy distribution of indoor light in the red area is often stronger than that of daylight and therefore small differences of reflection in the red area are more pronounced, as shown in *Panel 10*:

Panel 10: Metamerism

Metamerism

Reflectance



This problem is often due to the use of different dyes, pigments or materials. Fortunately metamerism can be evaluated numerically in most recipe prediction programs and can be included in the screening of any recipes to be printed out by the computer.

Conclusion

- Colour communication uses mathematical formulae to describe numerically the result of visual observation of colour or of a colour comparison, thus avoiding misunderstanding between suppliers and customers.
- Colour stylists do not invent new colours but rather promote existing ones.
- Practical application of economical colour measurement equipment and computers' match prediction has made shade matching and colour control systems easier and more reliable. 🌐

Literature sources and recommended reading

- Manfred Richter: *Einführung in die Farbmatrik*, 2. Aufl., Gruyter, Berlin 1980
- *Precise Color Communication: 2003 KONICA MINOLTA*
- MRoderick McDonald: *Colour physics for industry*, Society of Dyers and Colourists, 1987
- Official homepage CIE: <http://www.cie.co.at/>
- Wikipedia, the free encyclopedia: <http://www.wikipedia.org/>