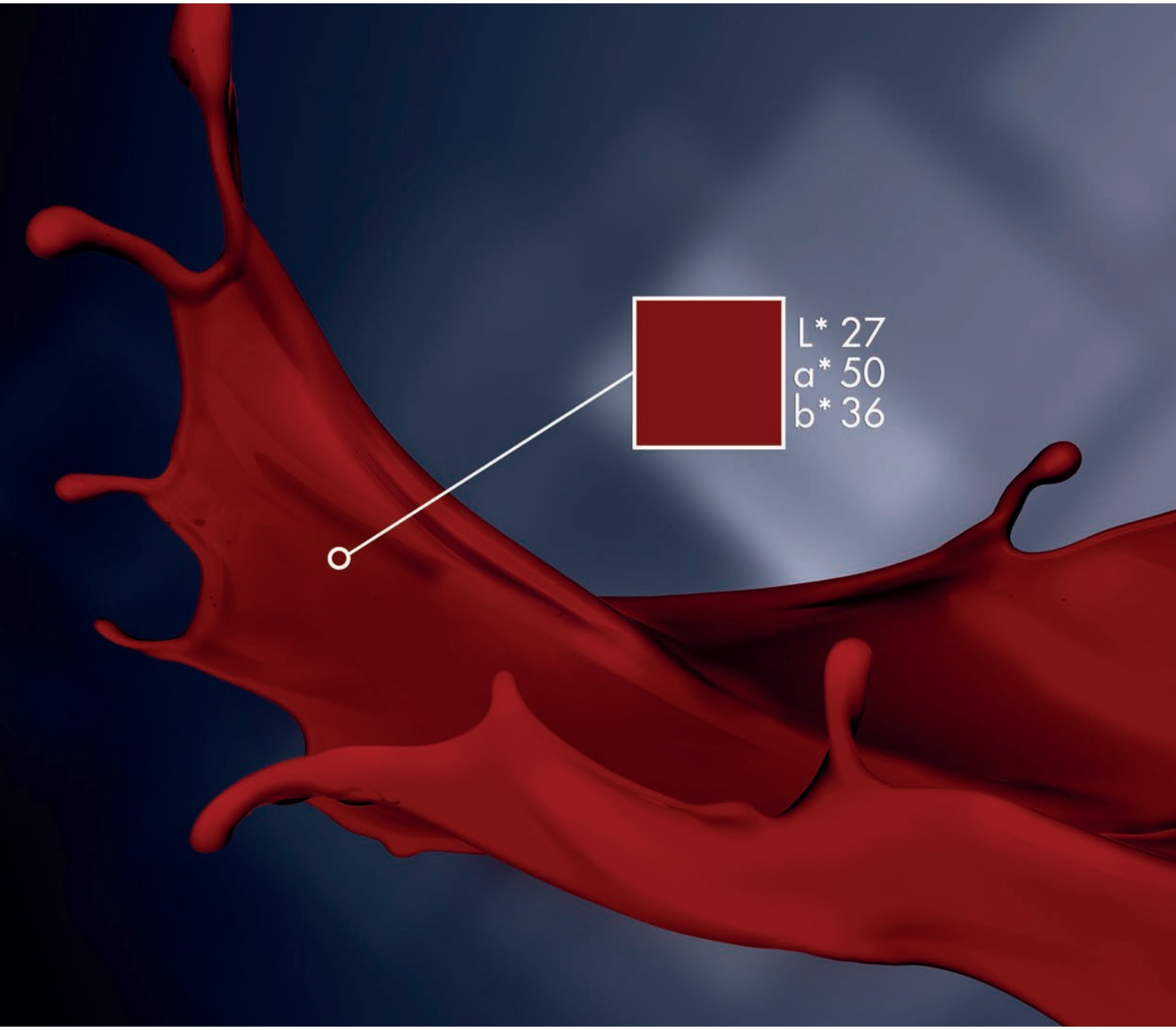
BOOK ONE OF COLOR MANAGEMENT



Color fundamentals and color perception

datacolor

Chapter 1

Introduction

What is color?

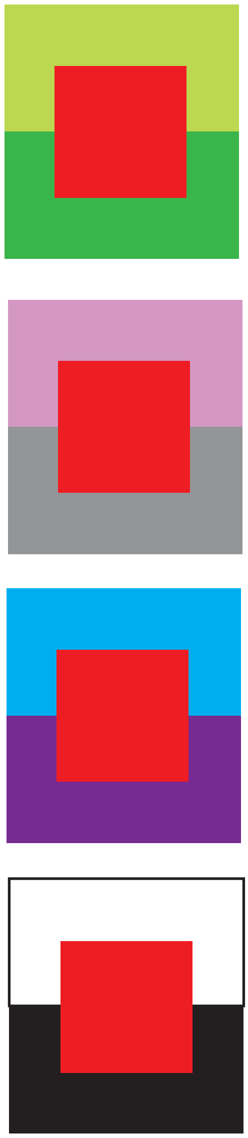
We live in a world rich in sensory experiences – sight, smell, taste, touch – which we are continuously sampling. Our visual system is an amazing tool. Using our ability to detect both subtle and large color differences, we process and discriminate millions of different colors. It is the basis for learning the shape, size and arrangement of objects in our world and we rely on it to successfully navigate our environment.

Our perception of color is not created at the moment of vision. Our experience of color is created through the exchange of information between the eye and the brain. The brain receives the sensory input from the receptors in the eye, and processes that information by applying a highly complex classification system. This is an instantaneous and ongoing process.

Color vs. Appearance

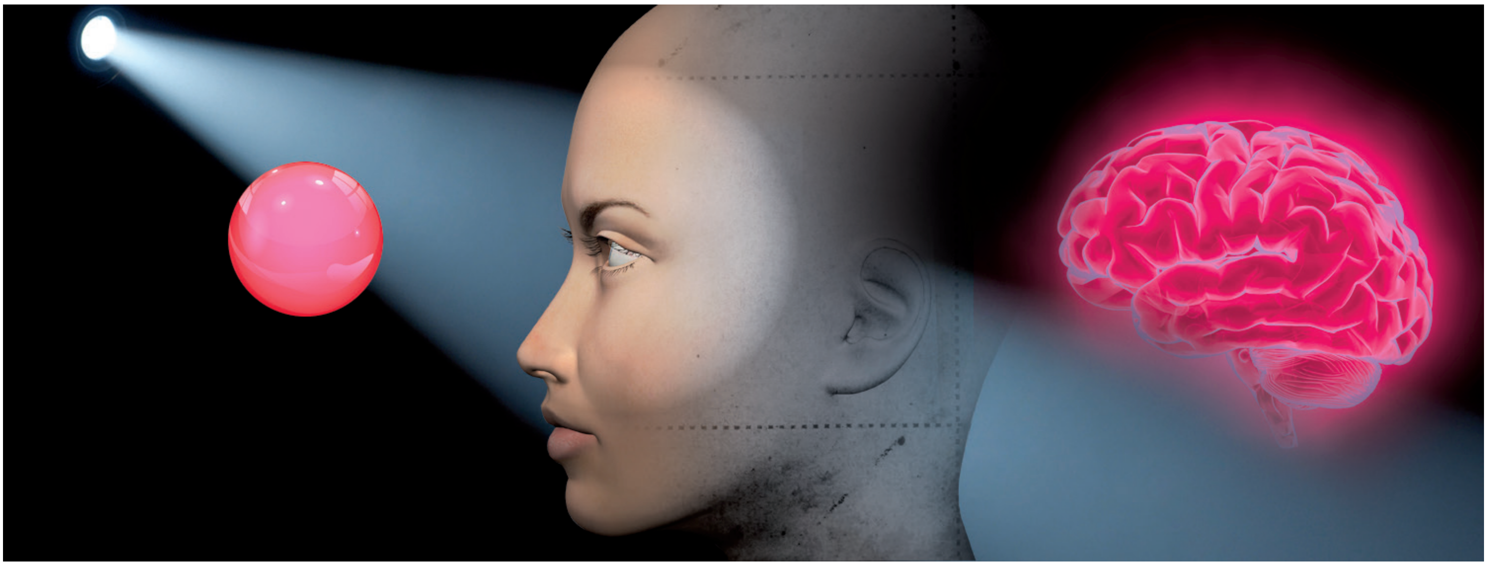
The experience we call color influences and is, in turn, influenced by other aspects of objects in our world. Texture, gloss, opacity – the look and feel of a surface – along with illumination all contribute to the color we perceive. However, we tend to separate those appearance attributes as being independent of the materials that color an object. For example, one may change the appearance of a plastic cup by embossing a texture into its smooth surface. In some lighting conditions, the change can dramatically change the cups' color. That mechanism is very different from creating a color change by changing the recipe of dyes or pigments used to make the plastic cup.

The eye/brain combination is far superior to any instrument/computer interface for integrating all of the visual information it receives. Instrumental color evaluation systems do not yet have the ability to accurately process color and appearance properties. However, they can precisely analyze the color of an object and have become invaluable tools in the specification, production and inspection of commercial products.



Red in different surroundings

Red in different light



The colors of objects

The objects in our world obtain their color by absorbing various rays and reflecting others (depending on the material). Water, for example, absorbs long-wavelength light much better than short-wavelength light. The red part of the sunlight is therefore already absorbed after a just a few metres under water. Going deeper, the orange, yellow and green colored parts disappear one after another. The blue light, on the other hand, is absorbed the least and reflected the most, so consequently it is reflected to the surface – and that is why our seas are blue. Nature's rich color spectrum is therefore nothing other than differently absorbed and reflected components of our sunlight. When we see color, we are basically seeing colored light that previously took a detour over the surface of an object.

The Visual System

Our eyes contain two types of cells, or photoreceptors, which are responsible for our experience of color. They are located in the retina.

- Rods are sensitive to overall lightness intensity, and they do not detect color. If rods were the only type of receptors present in our retina, we would live in a black-and-white world.
- Cones are responsible for our color vision. There are three different types of cones. Each type is sensitive to a different wavelength range, which corresponds to red, green and blue.

We also know that our color vision acuity depends upon the overall illumination level. In full daylight, the cones and the rods work together and produce a detailed picture of the scene we are viewing – both color and lightness levels. As the light fades only the rods receive sufficient stimulation, and the perception of color becomes increasingly limited. As the overall lighting level decreases we can only see shadows and shapes, but we no longer see color.

Understanding the physics of color vision made it possible to develop a method for measuring the response of the eye to color stimulus.

Eye and brain - a good team

Therefore, color is not simply there. It is generated only at the moment of vision. Our perception of color is composed from the cooperation between the eyes and the brain. The brain receives and processes the impulses of light and lightness according to a highly complex classification system, better than any computer in the world. Every moment, our vision is continuously processed and interpreted anew, and so we can perceive colors.

Chapter 2

Form of appearance and color

The first product claim

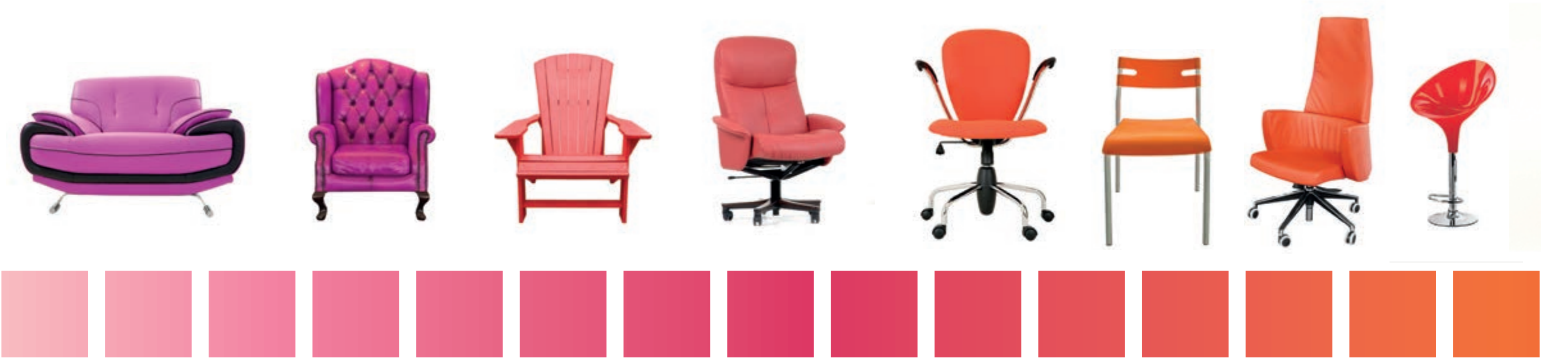
Our eyes provide sensory signals about objects in our environment and their properties, such as color, gloss, shape, texture, and transparency. However, this is not a direct translation of data in and awareness out. Before creating conscious perception, the brain samples and processes those sensory signals. The observer's experiences with similar objects, similar scenes, and lighting influence our mind's interpretations. Mood, age, and physical condition affect our judgments. Psychological/neurological processes transform sensory data into experience and subjective evaluation. Indeed, color is a psycho-physical phenomenon with perceptions of color extending beyond the recognition of objects to their favorability – whether they are pleasing or distasteful, desirable or repulsive or of high or low quality.

The Importance of Product Appearance

The psychological component of perception receives great attention in the design and manufacture of commercial products. Manufacturers know that observers connect a product's appearance to a specific purpose, and life span. If the product looks good, potential buyers will judge the performance, purpose, and durability of the product positively as well.

In addition to evaluating overall appeal, buyers often use color consistency to evaluate the quality of a product. Whether it is packs of coffee, chocolate, shirts or cars, consumers have come to expect branded products on display to look the same. In a group, the item that differs in appearance is judged as inferior, old, or defective. Consistent appearance increases buyer confidence in expectations of consistent performance and value. Given the choice, buyers select the product perceived as superior and familiar. The demand for color consistency extends from the product to its packaging and merchandising, and inconsistent color is a powerful de-motivator regarding product selection.

To ensure consistent product color, manufacturers adopt objective, technical specifications for evaluating their products. Precise color specifications have become an integral tool for the design, manufacture and inspection of virtually all commercial products. These specifications are derived from the principles of colorimetry. The discussions that follow will provide detail about fundamental principles of color science that are central to the specification and evaluation of colored products. They include considerations about the practical application of these principles in commercial coloring applications.



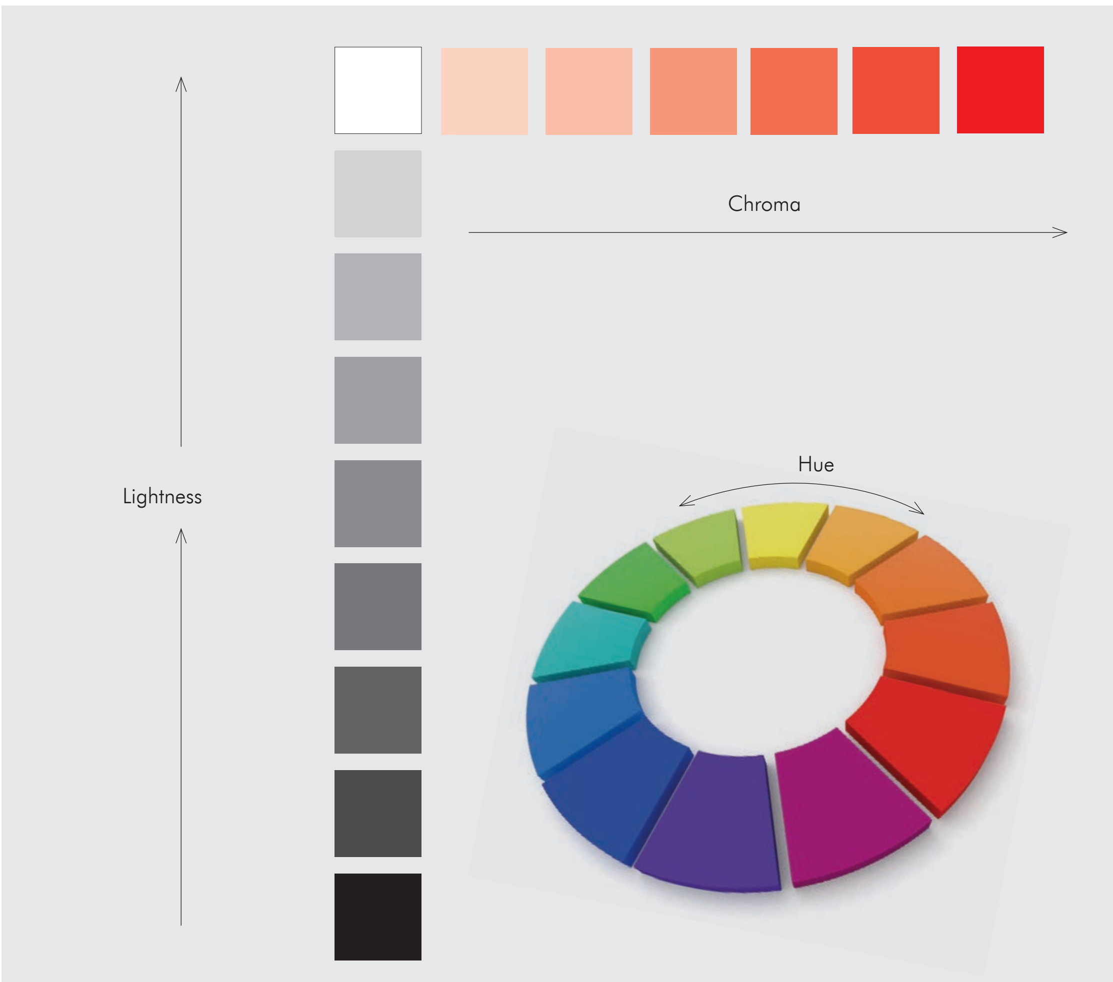
Chapter 3

The natural classification of colors

What is color?
Description of sensory perception

As very young children we detect and identify a wide variety of colors. Many children develop the ability to name colors shortly after they have learned to speak. However, while we live with a large palette of colors and we frequently talk about them, we lack the ability to precisely describe a color. If you ask 10 people about the color of an object, you will typically receive 10 different descriptions.

The three factors for the natural classification of colors



How Are colors Defined and Organized?

Scientists have run a variety of independent tests to determine if humans share an innate system for classifying colors. Each of these experiments provided the subject with a large sample of colors. The samples were similar in texture, but covered a wide range of colors. Despite the sample set used, a common set of organizing characteristics have appeared repeatedly in these experiments. All of the samples were organized by the observers based on 3 fundamental properties:

- The dominant color (hue)
- The intensity of the color (chroma)
- The lightness of the color (lightness)

The shade of the color (hue) describes what we commonly refer to as color. Although a perceived color is composed of multiple colors, it is typically concentrated within a particular range of the visible spectrum. This is the dominant color, violet, blue, green, yellow, orange, red, purple, etc. The basic hues in the visible spectrum are graphically represented via a circle, referred to as the color wheel.

Chroma describes the purity of a color. It is associated with the color intensity. A high chroma color produces an intense color, while low chroma color is perceived as a muted color. The words brighter and duller are commonly associated with this attribute.

Chroma is independent of hue, and is represented on the color wheel by its location along the radius of the color wheel. As the chroma of the color increases, the location of the color moves toward the edges of the color wheel.

Lightness locates the color along an overall lightness/darkness continuum, with white at the top and black at the bottom. It is a description of how much overall light is coming from the object. The lightness attribute is independent of the hue and the chroma.

This three dimensional system for organizing and classifying colors has become integrated into color space models, color difference equations and color tolerancing systems in wide use today.

The Color is characterised by the 3 factors in visual perception: hue (red), chroma/Colorfulness (vibrant) and lightness (light)

Classification system based on physical samples

Chromaticity diagrams and color atlases

Chromaticity diagrams are an aid to visualising a color. They primarily aid the representation and classification of colors and therefore enable a less subjective dialogue than the traditional use of language.

The simplest classification is a simple color palette. This is used even today for special products, e.g. for the refinement of sugar, for determining the degree of ripeness of fruit, and so on. This color palette generally exists in solid form (color scale) or in liquid form (in a test tube) and is numbered arbitrarily.

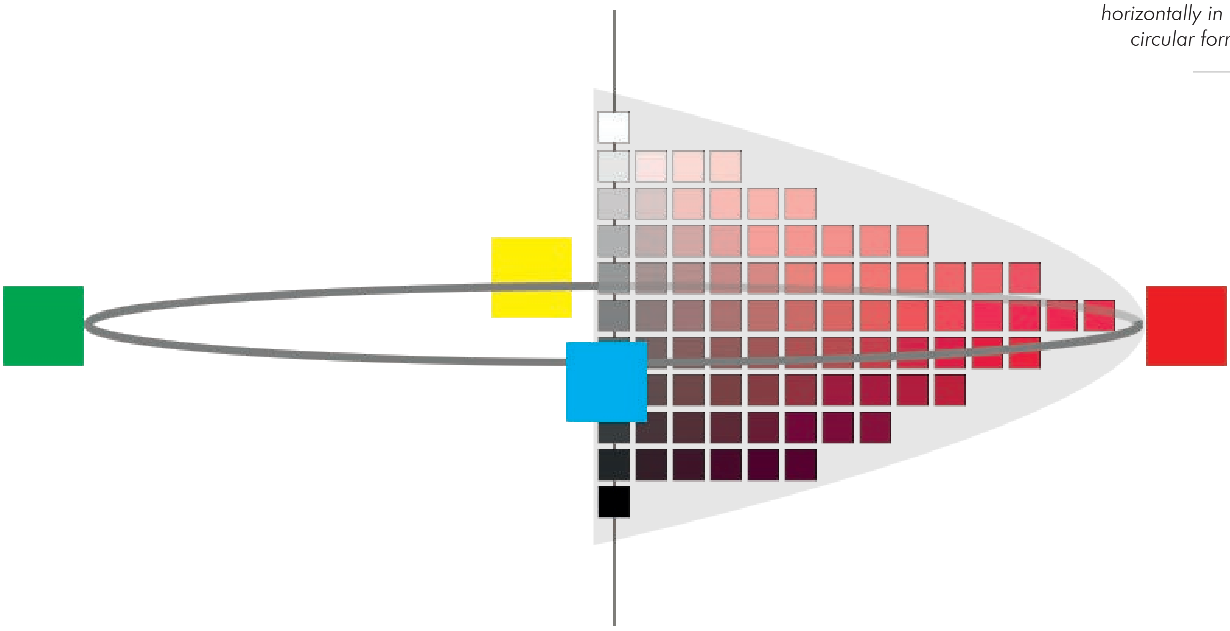
To represent a wide color spectrum, we turn to visual trivariance, that is, three-dimensional representation methods in the form of color atlases (also called color catalogues).

Color atlases represent colors as physical samples. Individual colors are shown by means of material samples (as a print, or plastic sample, for example) and a label is assigned. These systems are often linked with comparative color names. Color classification systems such as these allow the material visualisation of the colors that can be produced with the technology that is represented. This is an easy way for colors to be visually assessed.

Color classification systems must fulfil certain conditions:

- The color samples are classified mostly by perceived parameters, such as Shade (hue), Chroma and Lightness.
- The number of the physically produced color samples should be as large as possible. 20 to 40 color shades with five to ten lightness and chroma levels in each case results in a range of 500 to 4000 color samples.
- The color samples should be on a visually uniform scale.
- The color samples should be described numerically or alphanumerically in the form of tristimulus values or using classification tables.

The principle of the NCS Color atlas: vertical b/w axis and Color planes arranged horizontally in a circular form



There are various color atlases in circulation that are based on different approaches, but almost all of them use two basic principles:

- A vertical axis to represent the lightness (from black to white)
- The circular distribution of the dominant colors (or hues) around this axis

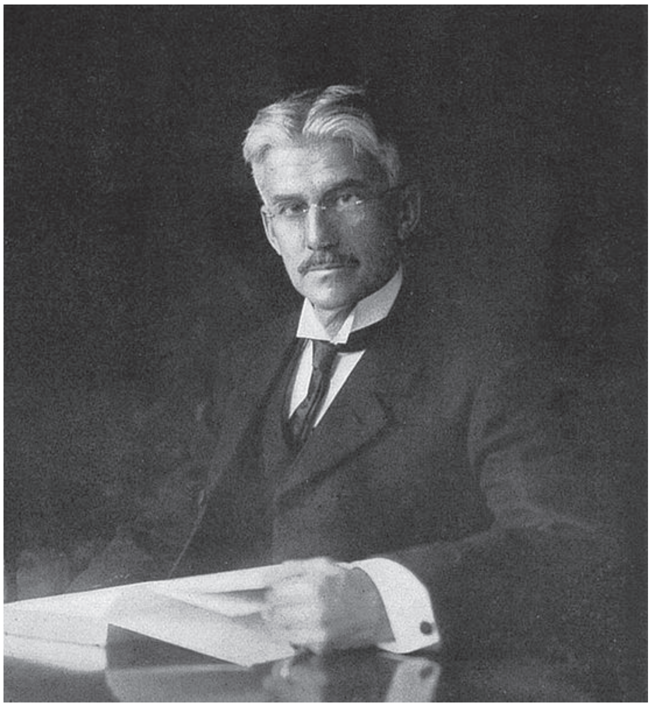
One of the most important works is the Munsell atlas (completed in 1905 and published in 1915). The Munsell system is one of the first complete color classification systems. This color system – the first internationally accepted color standard – is still in use today in a refined form in many areas, especially when it comes to the determination of color surfaces. The Munsell color system can also be seen as a forerunner of today's color standard, the CIE color system.

As a painter and professor of art, A. H. Munsell was interested in the classification of colors. For his three-dimensional color tree, he produced samples (chips), between which the visual color deviation was the most constant and most regular.

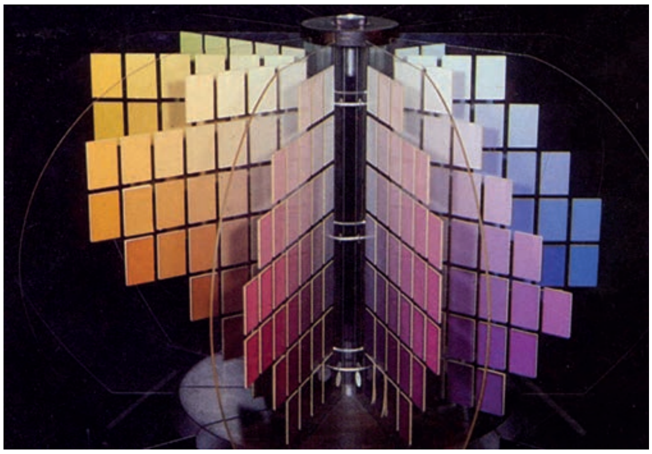
Other well-known color classification systems are:

- The DIN standard table
- The OSA (Optical Society of America) color system
- The NCS (Natural Color System) atlas
- The RAL Design system

To use the chromaticity diagrams efficiently, you must be aware of their precise limitations and disadvantages. Only the dyestuffs available on the market limit the physical feasibility of the samples. Color fastness and color retention are also dependent on time and are liable to ageing – the used products are rarely guaranteed for longer than 5 years. The color deviations between the individual samples are often too great at the edge of the color space and too small towards the centre.



The principle of the MUNSELL color atlas



The phenomenon of metamerism (*) also plays a role. In order to eliminate this, the chromaticity diagrams must be viewed under standardised, known, and reproducible illumination conditions, such as those found in light boxes. In addition to the classification systems, there are also color collections, such as RAL or Pantone, which are not compiled through a classification system, but represent commonly used colors that are widespread in the industry.

(*) More on the topic of "metamerism" can be found in chapter 11 on page 52.

List of references

- Farbe sehen, Corinna Watschke, 01.2009 [www.planet-wissen.de],
- Farbmanagement in der Digitalfotografie (ISBN 3-8266-1645-6), 2006, Redline GmbH, Heidelberg
- Beschreibung und Ordnung von Farben, Farbmetrik, Farbmodelle, DMA Digital Media for Artists – Archiv 2006-2011, Kunstuniversität Linz, Gerhard Funk
- Messen – Kontrollieren – Rezeptieren, Dr. Ludwig Gall [www.farbmetrik-gall.de]
- Farbabstandsformeln, 2012, Fogra Forschungsgesellschaft Druck e.V. [www.fogra.org]
- Wikipedia, diverse Artikel über Farbe und Farbmessung [http://de.wikipedia.org/wiki/Farbe]
- Verschiedene Darstellungen von Farbmodellen und Farbräumen [http://www.chemie-schule.de/chemieWiki_120]
- Praktische Farbmessung, Anni Berger-Schunn, 2. überarbeitete Auflage, 1994, Muster-Schmidt Verlag, Göttingen – Zürich
- Farbabstandsformeln in der Praxis, SIP 01.2011
- Schläpfer, K.: Farbmetrik in der grafischen Industrie, 3. Aufl. St. Gallen; UGRA 2002 (Tabelle S. 48)

Publication Data

Publisher:
Datacolor, Inc. 5 Princess Road, Lawrenceville, NJ 08648, USA
Telephone: 1-800-982-6497 | Fax: 609-895-7472 | Marketing@datacolor.com | www.datacolor.com

Text:
Gabriele Hiller, Hiller Direct Marketing, Stühren 41, 27211 Bassum, Germany
www.hiller-direct-marketing.de

January, 2023

EUROPE
Datacolor AG Europe
6343 Rotkreuz
Phone: +41 44.835.3800

AMERICA
Datacolor Headquarters
Lawrenceville, NJ
Phone: +1 609.924.2189

ASIA
Datacolor Asia Pacific Limited
Hong Kong
Phone +852 24208283

www.datacolor.com