VISUAL DICTIONARY OF COLOUR

Colour Society of Australia NSW Division International Colour Day exhibit, National Art School, Sydney, March 21st - 24th 2017

Text: Dr David Briggs, Chairperson, NSW Division, Colour Society of Australia

Colour Society of Australia

Knowledge
Inspiration
Community

International Colour Day
21 March
Established by AIC – International Colour Association

Effective thinking and communication about colour depends on the existence of a mutually agreed and unambiguous vocabulary. For fundamental terms relating to what colour is and how it can be described and specified, by far the most comprehensive and authoritative standard is the *International Lighting Vocabulary* of the *International Commission on Illumination* (CIE, 2011)[1]. However the verbal CIE definitions, including those of the six fundamental perceived colour attributes of hue, brightness, lightness, colourfulness, chroma and saturation, can be difficult for non-specialists to understand without additional explanation and illustration. In addition, the CIE definitions do not cover many terms relating to applied colour that are important to artists and designers. For such terms we often must acknowledge a number of conflicting usages associated with different traditions.

To celebrate International Colour Day 2017 the NSW Division of the Colour Society of Australia produced an exhibit on the theme *Visual Dictionary of Colour* at the National Art School, Darlinghurst, Sydney. The bulk of the works to be exhibited were produced by students at the National Art School in the *Visual Dictionary of Colour* workshop that I conducted there in Margaret Olley Drawing Week at the start of the academic year. The brief of the workshop was to contribute to an exhibition illustrating specific colour-related terms using media of the students' choice, including drawing, painting, photography, digital illustration and 3D models. The student works were supplemented with some digital illustrations made by myself for a chapter on *Colour Spaces* for the forthcoming *Routledge Handbook of Philosophy of Colour*, and for my website *The Dimensions of Colour* (www.huevaluechroma.com), and also with student exercises and teaching demonstrations associated with the history of the National Art School.

The Colour Society is very grateful to the staff of the National Art School for their assistance with the workshop and the exhibit, especially to Head of Drawing Dr Maryanne Coutts for making available a space for the exhibit, to NAS archivist Deborah Beck for making historical items available for photography and display, to artist and teacher Jocelyn Maughan for permitting me to photograph many of her teaching materials, and to the students from my workshop and Public Programs classes at the National Art School who loaned their works for the exhibit. Materials from the National Art School Collection are reproduced here by kind permission of NAS archivist, Deborah Beck.

David Briggs

[1]International Commission on Illumination/ Commission Internationale de L'Eclairage, (2011). *International Lighting Vocabulary*. CIE S 017/E:2011. Searchable online at http://eilv.cie.co.at/

CONTENTS

PART 1: WHAT IS A COLOUR?

Colour

Colour (perceived)*:* "characteristic of visual perception that can be described by attributes of hue, brightness (or lightness) and colourfulness (or saturation or chroma)" (CIE, 2011, 17-198).

Colour (psychophysical): "specification of a colour stimulus in terms of operationally defined values, such as 3 tristimulus values"[1] (CIE, 2011, 17-197).

The view of the fundamental nature of colour embodied in the CIE definitions quoted above may be said to have three elements. First, qualities of colour such as hue, lightness and chroma are attributes of *visual perception*. Second, we must make a distinction between colour perceptions and the properties of lights and objects that we *see as* their colour. Third, the property of a light or an object that we perceive as its particular colour is a *psychophysical* property, meaning that it is not simply physical, but involves the perceiver as well as the stimulus in its definition.

[1]Tristimulus values are in turn defined as the "amounts of the 3 reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered" (CIE, 2011, 17-1345).

Perceived Colour and Psychophysical Colour

The distinction between colour perceptions and the properties of lights and objects that we *see as* colour can be traced back to antiquity via Descartes, Locke and Galileo, but begins in substantial detail with Sir Isaac Newton's researches into the physical basis of colour. In the well-known passage from his *Opticks* (1704) shown below Newton explicitly distinguishes between colour as a psychological perception ("sensation") and the properties we call colours "in the rays" and "in the object".

Below: Extract from Newton's *Opticks* (1704).

DEFINITION.

The homogeneal light and rays which appear red, or rather make Objects appear ſo, I call rubrific or red-makng ; thoſe which make Objects appear yellow, green, blue and violet, I call yellow-making, green-making, blue-making, violet-making, and ſo of the reſt. And if at any time I ſpeak of light and rays as coloured or endued with Colours, I would be underſtood to ſpeak not philoſophically and properly, but groſſly, and according to ſuch conceptions as vulgar People in ſeeing all theſe Experiments would be apt to frame. For the rays to ſpeak properly are not coloured. In them there is nothing elſe than a certain power and diſpoſition to ſtir up a ſenſation of this or that Colour. For as ſound in a Bell or muſical String, or other ſounding Body, is nothing but a trembling Motion, and in the Air nothing but that Motion propagated from the Object, and in the Senſorium 'tis a ſenſe of that Motion under the form of ſound ; ſo Colours in the Object are nothing but a diſpoſition to reflect this or that ſort of rays more copiouſly than the reſt ; in the rays they are nothing but their diſpoſitions to propagate this or that Motion into the Senſorium, and in the Senſorium they are ſenſations of thoſe Motions under the forms of Colours.

Metamerism

For Newton, colours “in the rays” are their "power" or "disposition" to be seen as this or that perceived colour, which for an isolated light depends on the relative balance of the component "rays" (we would now say wavelengths), represented approximately by their "center of gravity" in his colour circle (Fig. 7.1.5). This position is neither a purely physical nor a purely psychological property, but involves a relation between the two, now called *psychophysical*. A psychophysical colour specification represents a class of physically varied stimuli that are indistinguishable to an observer, such as the CIE 1931 standard colorimetric observer.

As Newton’s diagram implies, most colours of light can be evoked by many different combinations of "rays" having the same centre of gravity. This means that a given colour of light does not correspond to a single physical combination of "rays" but to a whole class of combinations (we would now say spectral power distributions, Fig. 1.2.3) that happen to be indistinguishable to the human visual system. We now call members of such a class *metameric*, and believe that they are indistinguishable to human vision because they evoke the same relative response of the three cone cell types on which our colour vision depends.

Below: 1. Newton hue circle (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/071.php). 2. Three metameric “warm white” lights in the CIE xy chromaticity diagram, a modern descendant of Newton’s circle (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/012.php).

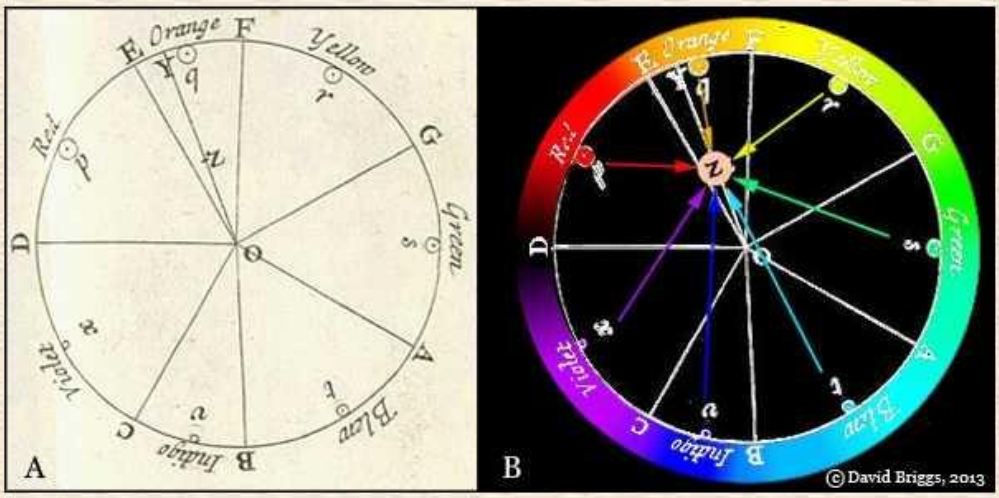


Figure 7.1.5. **A. Colour circle from Newton's *Opticks* (1704), showing a desaturated orange light mixture (z) at the "centre of gravity" of its seven unequal spectral components, indicated by circles of differing size. Source:Posner Library. B. Coloured version of Newton's diagram, showing the interpretation of Newton's hue names adopted here. The spacing of the red through violet hues is taken unchanged from my linear RGB circle (Fig. 4.3.4), so that opposed spectral hues in the diagram are true additive complements.**

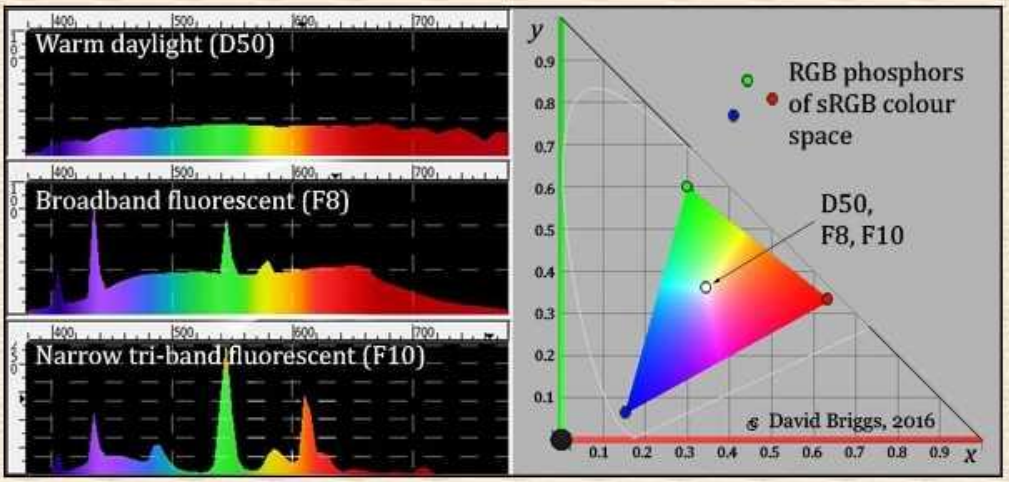


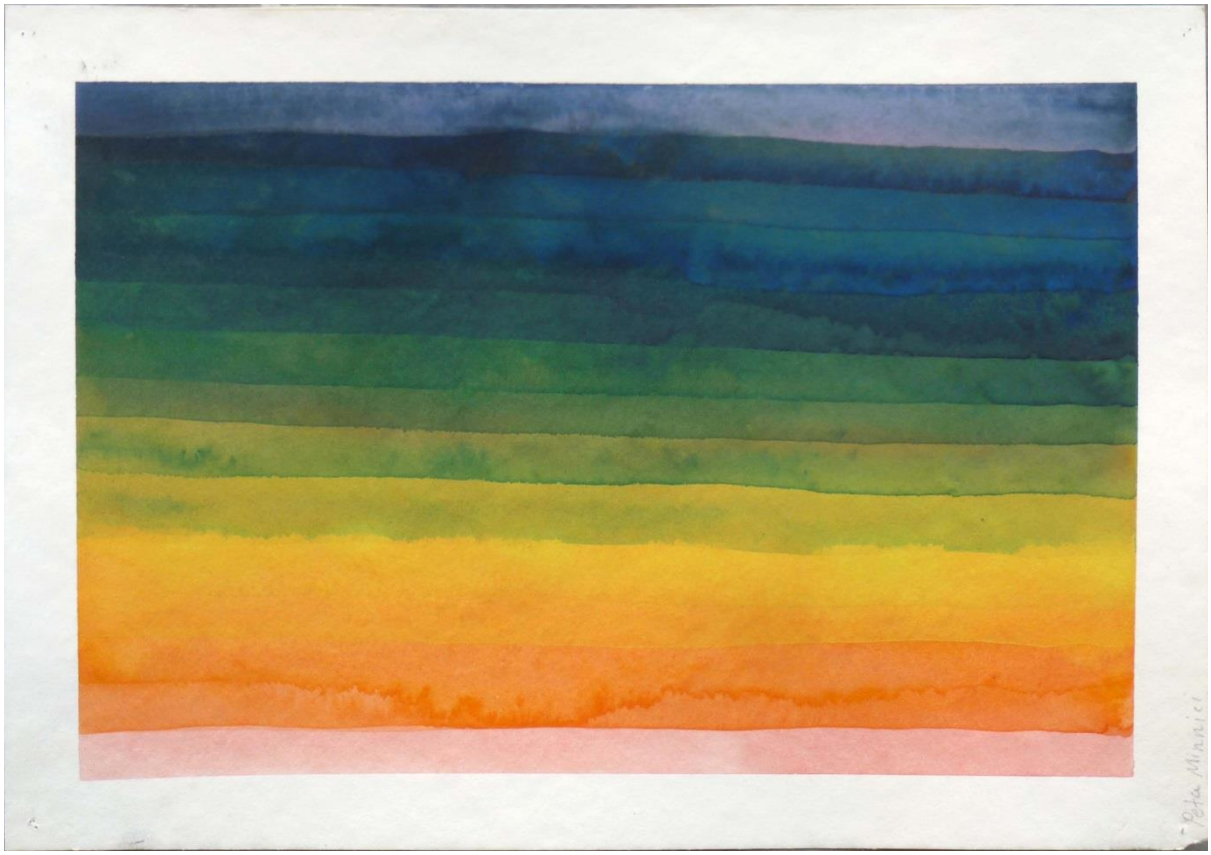
Figure 1.2.3. **Left: Spectral power distributions of three standard white *illuminants* (light sources). Though very different physically, these three lights have the same *chromaticity* (psychophysical colour considered separately from brightness/luminance) and appear the same colour (a warm white). Right: CIE xy *chromaticity* diagram showing chromaticities of the RGB lights of a standard RGB colour space (sRGB) and of the three illuminants shown on the left. The faint horseshoe-shaped line shows the chromaticities of the monochromatic wavelengths of the spectrum. All images derived from the program *ColorSpace* by Philippe Colantoni.**

Spectrum

Spectrum: term originally introduced by Newton for the rainbow-like band of light produced by splitting a beam of sunlight using a prism.

Newton's solar spectrum, like the spectrum of the filtered incandescent bulb of a 35 mm slide projector (below), shows a relatively smooth distribution of energy (called a *spectral power distribution*). Other white light sources such as fluorescent tubes have a much more "spiky" spectral power distribution (see under *Metamerism*), producing a spectrum of discrete coloured bands.

Below: 1. Photograph of the spectrum of a 35 slide projector by Clayton Croker, *Visual Dictionary of Colour* workshop, 2017. 2. Spectrum painted in watercolour washes by Peta Minnici, *Visual Dictionary of Colour* workshop, 2017.



Spectral Reflectance

Spectral reflectance: reflectance of an object at each wavelength of the spectrum.

Newton also discovered that the particular colour of an object depends on the object's "disposition to reflect this or that sort of rays more copiously than the rest". We now call this disposition its spectral reflectance). As with colours of light, a whole class of spectral reflectances are indistinguishable (metameric) to the human visual system under the same illumination, so that the particular colours of objects are also psychophysical rather than purely physical properties.

By shining a spectrum onto paint samples it is possible to directly demonstrate which wavelengths each paint samples reflects and which wavelengths it absorbs. For example, all bright yellow paints efficiently reflect most of the red, orange, yellow and green wavelengths that fall on them.

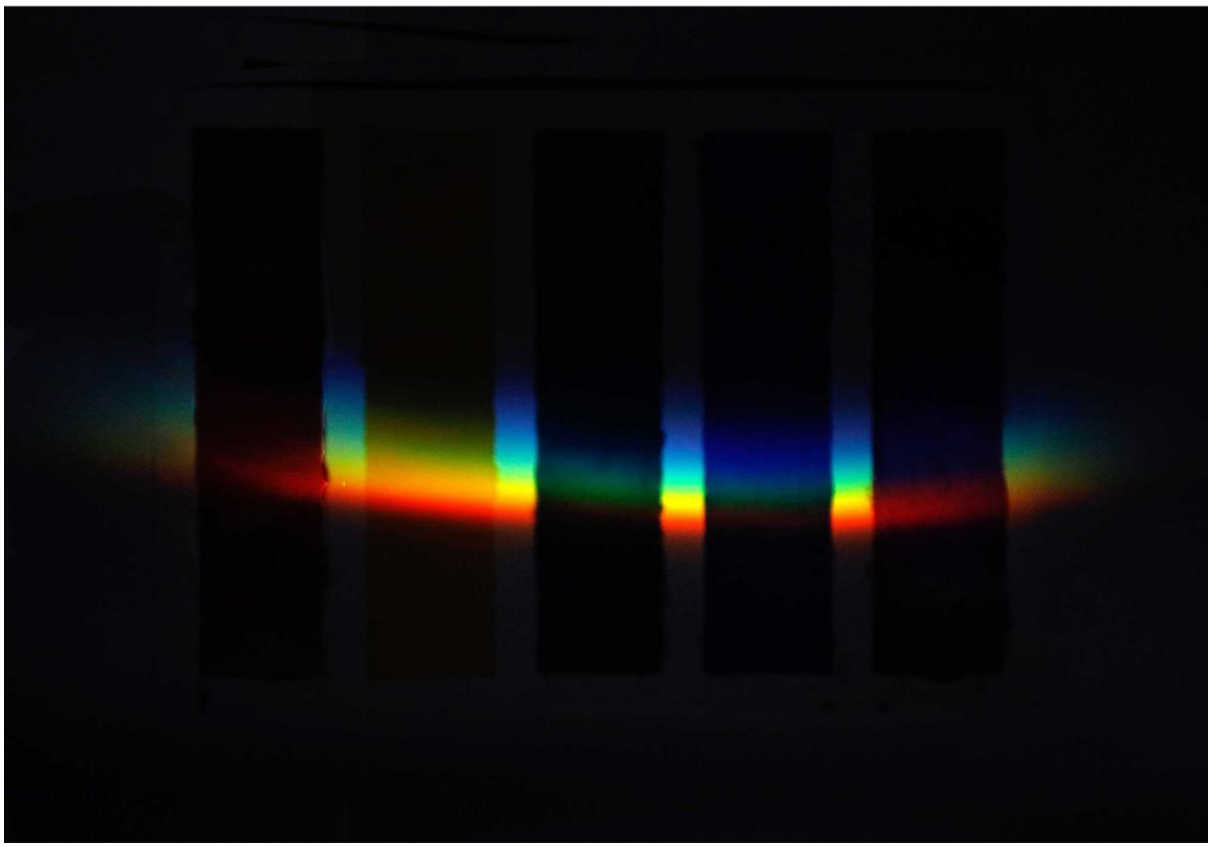
Below: Red, yellow, green, blue and magenta paint samples under white light (above) and under the spectrum of a 35 mm slide projector (below), photographed by Clayton Croker and Jess Amos *Visual Dictionary of Colour* workshop, 2017.

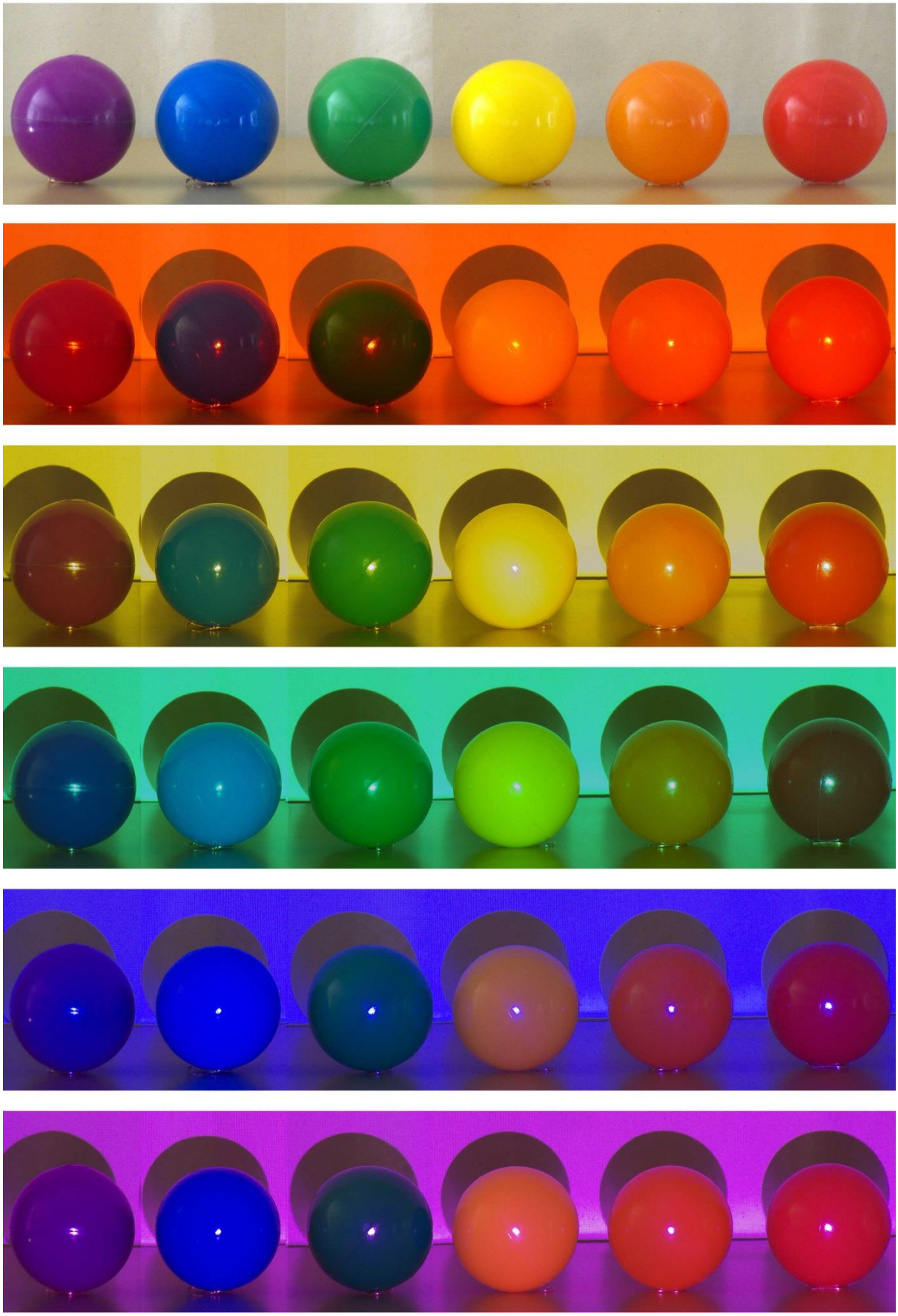
Illuminant

Illuminant*:* radiation with a relative spectral power distribution defined over the wavelength range that influences object colour perception. NOTE In everyday English this term is not restricted to this sense, but is also used for any kind of light falling on a body or scene (CIE 2011, 17-554).

The reflectance of an object depends on the product of the balance of wavelengths (spectral power distribution) of the light source (illuminant) and the spectral reflectance of the object. The effects of coloured illumination follow the principles of subtractive mixing, since only wavelengths present in the light source and not absorbed by the surface can be reflected. Coloured lighting tends to neutralize and darken complementary-coloured surfaces, while similar coloured objects increase in lightness relative to neutral objects. Colours also shift towards the hue of the coloured light.

Below: Six coloured spheres under different coloured illuminants, photographed by Clayton Croker, *Visual Dictionary of Colour* workshop, 2017.





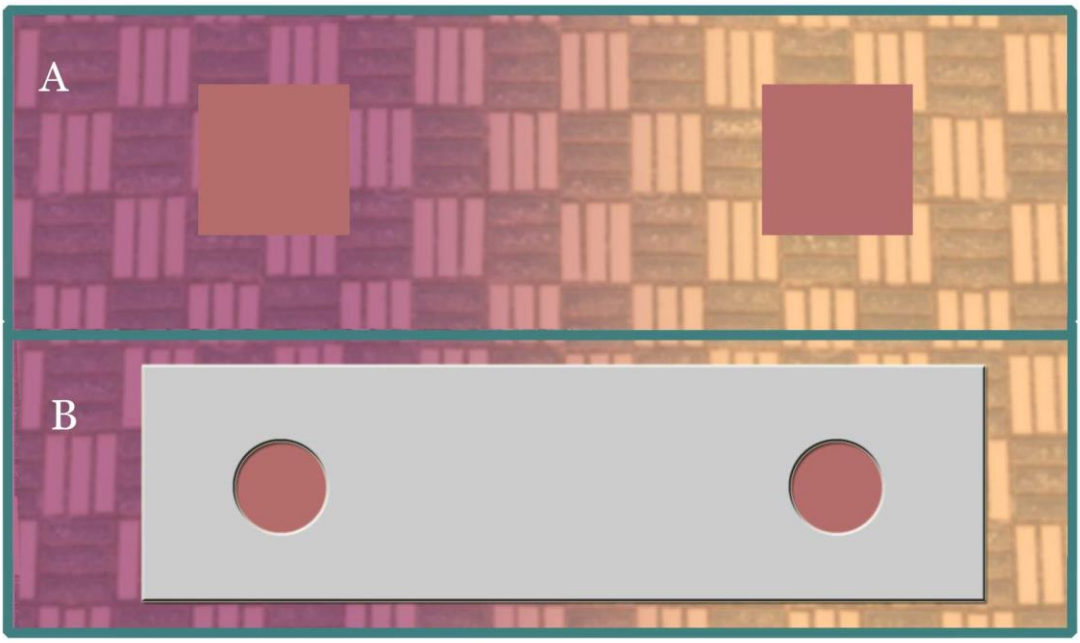
Simultaneous Contrast

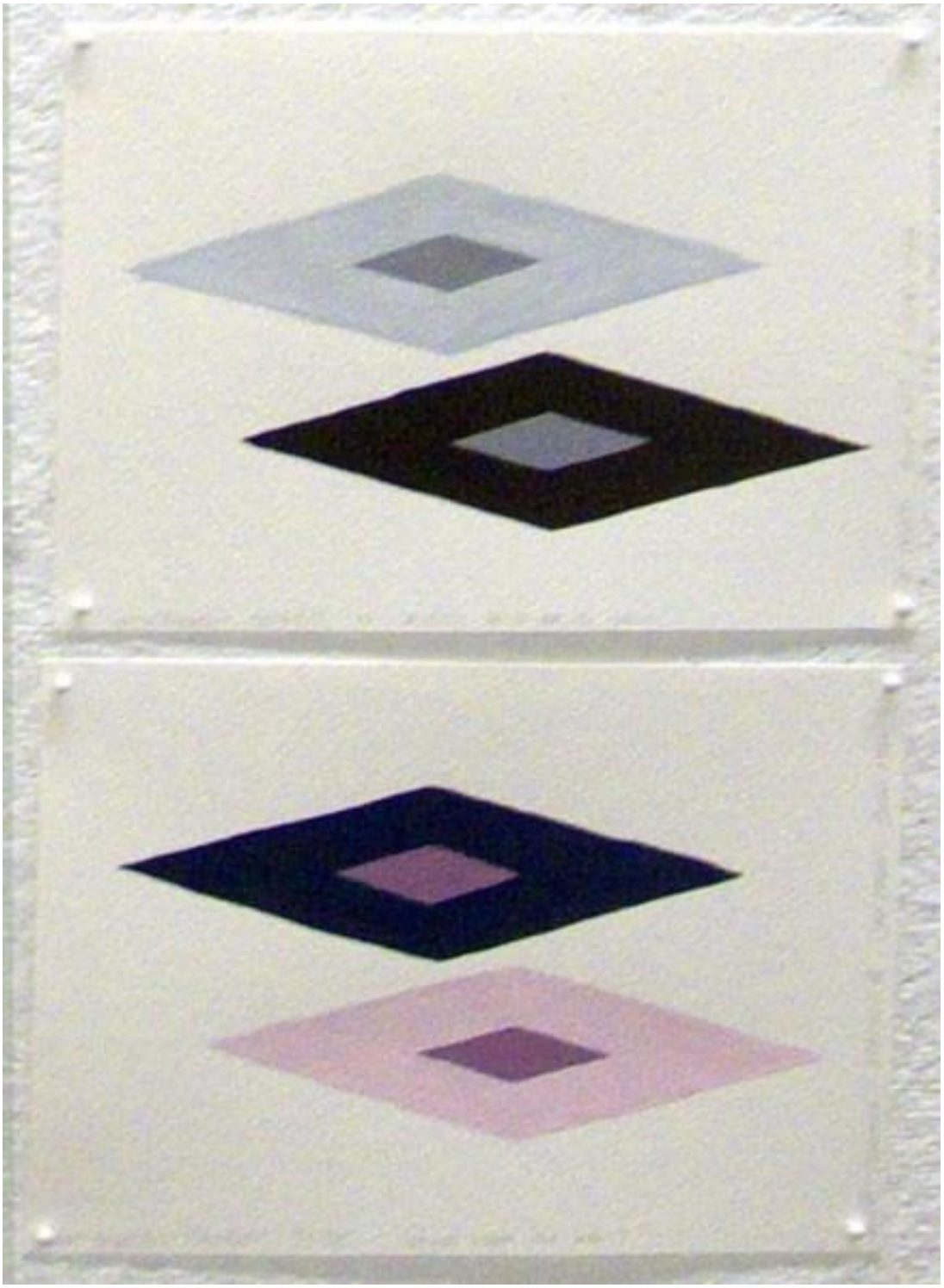
Simultaneous contrast: change in perceived colour when two areas with the same colour specification (psychophysical colour) are placed in different surrounds. In simultaneous contrast the perceived colour of an area tends to move away from the colour of the surround in hue, value and/or chroma.

Below: 1. Two squares having the same psychophysical colour specification (R180 G108 B108 as an sRGB screen colour, 5R 5/6 as a Munsell notation) have different perceived colours when viewed in different contexts (A) but match when viewed in the same context (B) (David Briggs, *Colour Spaces* in *Routledge Handbook of Philosophy of Colour*, in press).

2,3. Demonstrations of simultaneous contrast using gouache. The same paint colour appears darker against a light background and lighter against a dark background. Elizabeth Creixell, *Visual Dictionary of Colour* workshop, 2017.

Figure 2





PART 2: THE ATTRIBUTES OF PERCEIVED COLOUR

The six attributes mentioned in the definition of perceived colour - *hue, brightness, lightness, colourfulness, saturation* and *chroma* - are all defined perceptually, that is, as attributes of visual perception rather than as physical properties of lights or objects. None of the six are alternative names for the same thing: a perceived colour can be described in terms of hue, lightness and chroma if it is seen as belonging to an illuminated object, or in terms of either hue, brightness and saturation or hue, brightness and colourfulness if it is seen as belonging to light.

Another set of perceived attributes of object colours, not currently defined by the CIE, consists of proportions of black, white and colour content considered as perceived components of an object colour. Black content or *blackness* is however used as a dimension in the historical Ostwald System and in the modern Scandinavian Natural colour System, and in his book *The Perception of Color* (1974) Kodak scientist Ralph Evans introduced the term *brilliance* for this scale from blackness to luminosity.

Below: Attributes of colours perceived as belonging to (A) objects and (B) light (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/011.php).

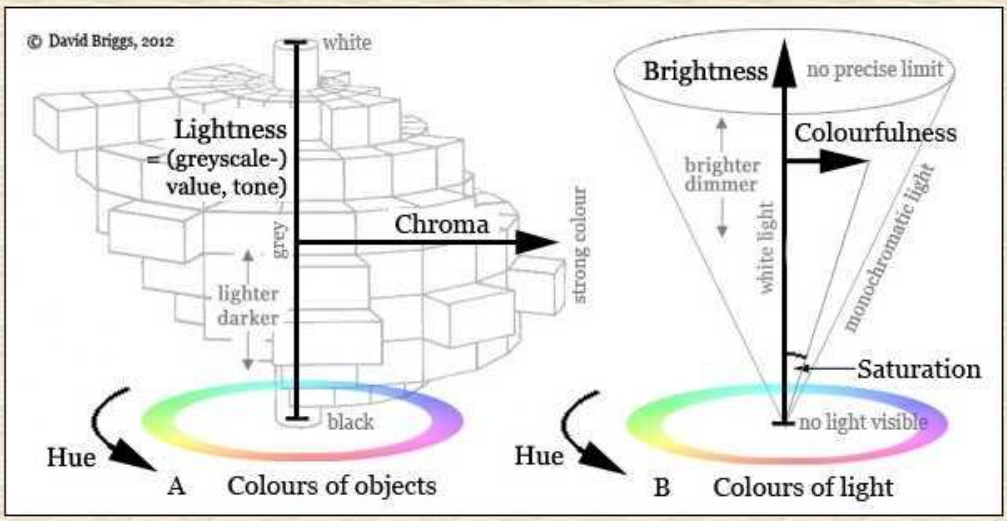


Figure 1.1.4. **Attributes for colours perceived as belonging to (A) objects and (B) light.** ***Saturation*** **refers to purity of colour of light, and can vary throughout its range (white to monochromatic) at any level of brightness; it is represented in B by the angle from the neutral axis. Colourfulness refers to strength of colour of light, and can be thought of as saturation times brightness; it is represented in B by the distance from the neutral axis.** ***Chroma*** **(strength of colour of objects) depends on the colourfulness (saturation and brightness) of the light given off by an object for a given level of illumination. Chroma is necessarily zero at maximum and minimum value (white and black respectively), and reaches its maximum range at intermediate value levels.**

Lightness

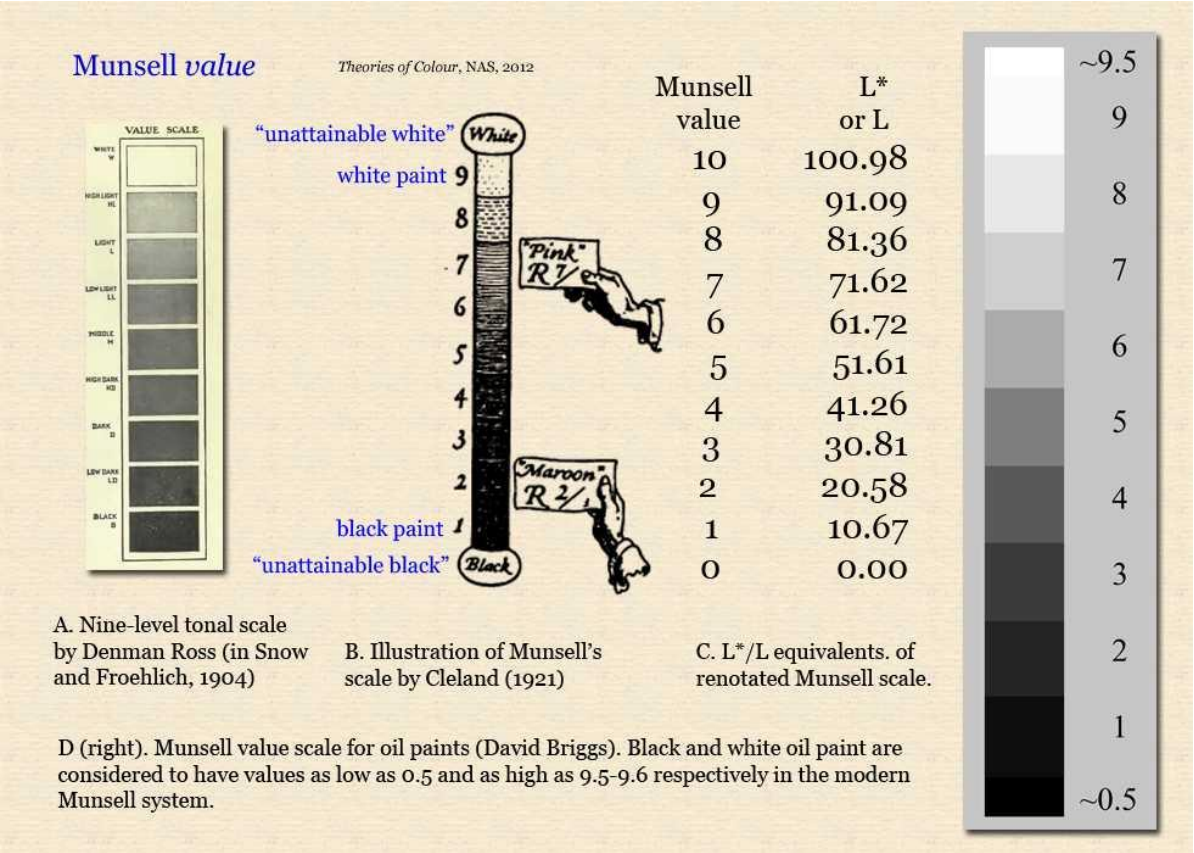
Lightness: "brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting" (CIE 2011, 17-680).

Lightness, value, greyscale value, and *tone* are all very closely related or identical in meaning. Lightness, value and greyscale value refer to the scale from black through various shades of grey to white, increasing in that order. The word tone as used by painters refers (in one of its senses) to the same scale, but may be deemed to increase from white to black. Lightness is how we perceive the *luminous reflectance* of an object.

Painters most commonly specify lightness in terms of *Munsell value* in traditional media and in terms of *Lightness (L)* in Lab colour space (based on CIE L*a*b* space) in digital painting.

If the lightness information in an image is isolated from the chromatic information, remarkably large amounts of the legibility and compositional structure are preserved

Below: 1. Lightness scales used by painters, David Briggs, NAS AHT elective *Theories of Colour*. 2. Demonstration of importance of lightness content in a pictorial image. (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/014.php).



A. *Sunlight Sweet* (Streeton, 1890) B. Lightness (value) information C. Hue and chroma information

Figure 1.3.1. **A. *Sunlight Sweet, Coogee* (1890) by Arthur Streeton. B, value/ lightness and C, hue and chroma information.**

Value Study

A copy or study painted using a series of greyscale mixtures, with the purpose of developing an awareness of absolute value (lightness).

Munsell-based value scales used by painters and painting teachers generally have either nine or eleven levels, counting black and white paint as levels one and nine, or zero and ten, respectively. A nine-level Munsell-based value scale was used at NAS in the 1950's in the colour course of Phyllis Shillito, and at Meadowbank TAFE in the 1970's, under the evident influence of Maitland Graves' 1941 book *The Art of Color and Design* (see below under *Value Key*, *Value Interval* and *Value Chord*).

Below: 1. Painting copy exercise in Munsell greyscale values, Juliemma Moran. 2. Still life painting exercise in Munsell greyscale values, Alexia Manzoni. Both from *Oil Painting with Colour and Light* (NAS public programs course, teacher David Briggs), Term 1, 2017.

Hue

Hue: "attribute of a visual perception according to which an area appears to be similar to one of the colours: red, yellow, green, and blue, or to a combination of adjacent pairs of these colours considered in a closed ring" (CIE, 2011 17-542).

The hue of any colour is its closest match in the circuit of "pure" or "saturated" colours known to artists as the colour wheel. Thus the hue of a brown object is the particular orange-yellow to orange-red that it most closely resembles.

The CIE definition of hue attributes the cycle of hues to successive combinations of four hues identified in a separate definition as the "unique" or "unitary" hues, in acknowledgment of the widely accepted theory of colour opponency. By this theory, hue perceptions are generated in the visual system in the form of red/green and yellow/blue perceptions or “signals” based indirectly on information from the relative cone responses of the retina. Colour opponency is also explicitly acknowledged in the hue circle of the Scandinavian *Natural Colour System* (NCS).

Below: Generation of spectral colours according to the colour-opponent model of colour vision (David Briggs, *The Dimensions of Colour*, http://www.huevaluechroma.com/014.php).

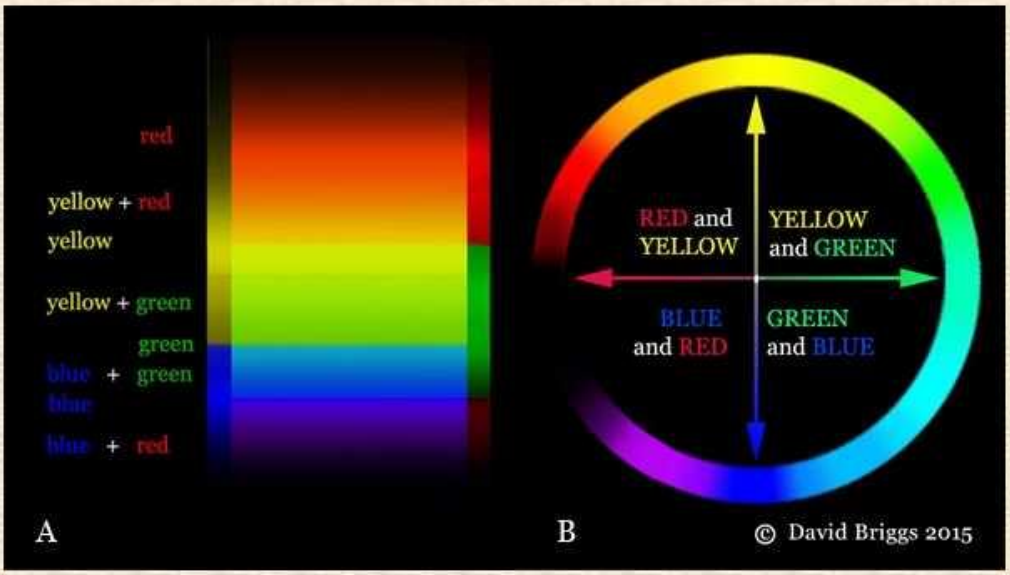


Figure 1.4.4. **Spectral hues explained as successive combinations of yellow/blue and red/green colour-opponent hue perceptions.**

Hue is how we perceive the direction of bias of the spectral power distribution of a light (its distribution of energy through the spectrum) or of the spectral reflectance of an object (its reflectance through the spectrum). In general terms a yellow *vs* blue perception is evoked by long or middle *vs* short wavelength dominance, while a red *vs* green perception is evoked by long OR short *vs* middle wavelength dominance

For example, paints that strongly reflect the middle and long wavelength parts of the spectrum are seen as being strongly yellow, and either slightly greenish, slightly reddish, or neither depending on the relative size of the middle and long wavelength contributions. In *Gamblin Cadmium Yellow Light* (below) these contributions are approximately evenly balanced and the paint is seen as middle yellow, neither greenish nor reddish, while in *Gamblin Cadmium Yellow Medium* the contribution from the middle (green-evoking) part of the spectrum is smaller, and so the paint colour is seen as having a red component (Fig. 1.4.5). *Titanium White* is seen as being neutral because its spectral reflectance has no substantial bias.

Below: Effect on perceived hue of a small difference in bias of spectral reflectance between two yellow artists' paints (David Briggs, *The Dimensions of Colour*, http://www.huevaluechroma.com/014.php).

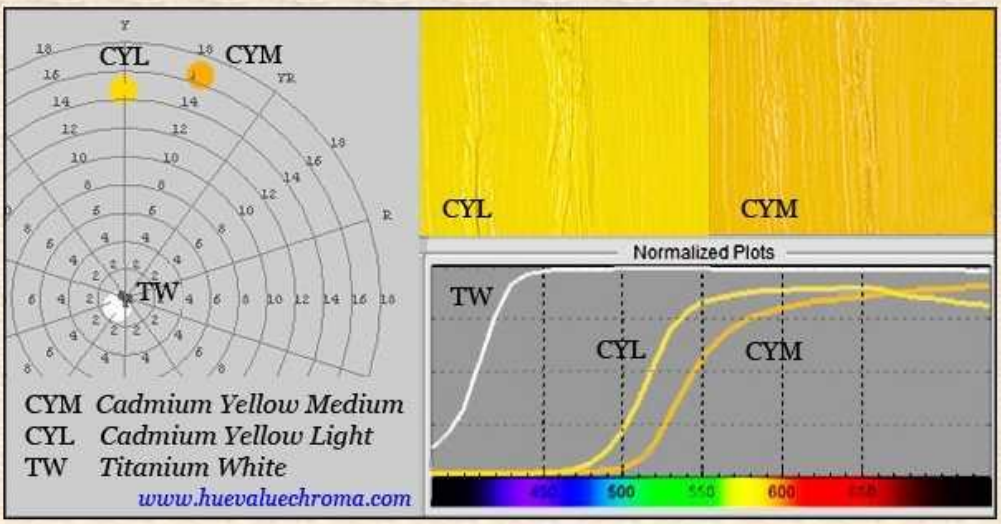
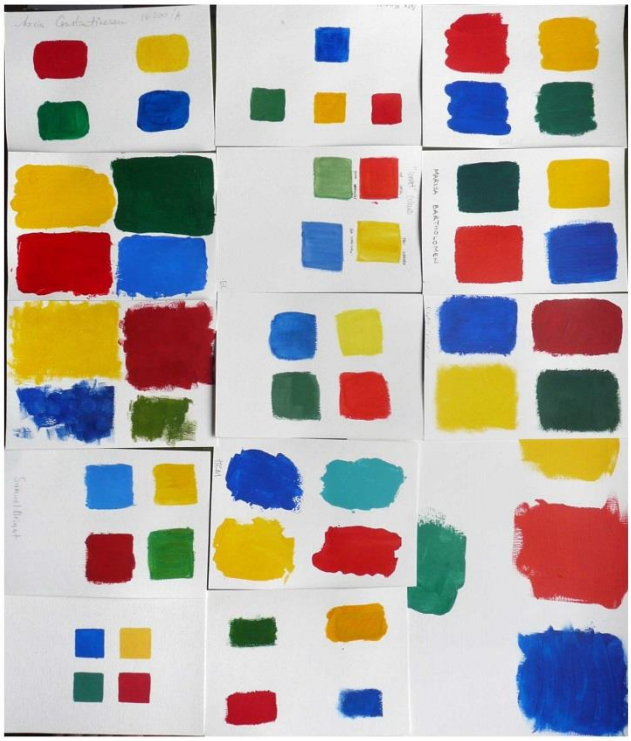


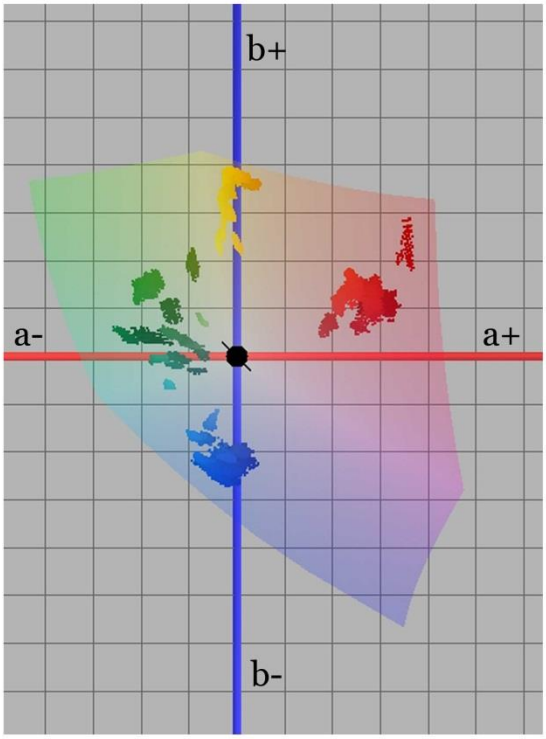
Figure 1.4.5. **Comparison of spectral reflectance curves of Gamblin *Cadmium Yellow Light*, *Cadmium Yellow Medium* and *Titanium White* oil paint. Munsell plot and spectral reflectance curves for Gamblin Conservation Colours from *drop2color* by Zsolt Kovacs Vajna; paint sample photos from dickblick.com.**

Unique Hue

Unique hue: "hue that cannot be further described by the use of hue names other than its own. Equivalent term: "unitary hue". NOTE There are 4 unique hues: red, green, yellow and blue forming 2 pairs of opponent hues: red and green, yellow and blue." (CIE, 2011, 17-1373).

Below: Left, paint swatches supplied by fifteen students of the 2017 *Visual Dictionary of Colour* workshop as representative of the hue that appears unique red, yellow green and blue to them. Right, photographed colours of all fifteen supplied colour swatches plotted in CIE L*a*b* colour space using the program *ColorSpace* by Philippe Colantoni. The general positions of each hue group and the particularly high variation in choices of unique green both align with published studies based on choosing Munsell colour chips.





Student Hue Circle Exercises

1. Munsell hue circle exercises by Tony Tuckson, Sydney Technical College, 1947-49. The circles are labelled with the Munsell principal hues (R, Y, G, B, and P) and abbreviations for specific pigments, probably including alizarin crimson ("AC"), chrome yellow ("CrY"), cerulean blue ("CerB"), prussian blue ("PrB") ultramarine ("UL"), yellow ochre ("Yo") venetian red ("VR"), indian red ("IR"), light red ("LR") and lamp black ("LBlack"). National Art School Collection.

2. Colour wheel exercise by Jocelyn Maughan from the colour class taught by Phyllis Shillito within the Diploma course at East Sydney Technical College in 1958. Shillito's "N_o 1" colour wheel is a distinctive 15-hue arrangement with each of the three traditional "primary colours" represented by two specified pigments representing a warm and a cool version of each, plus three "secondary colours" and six intermediate "Sub-primary colours". Collection of Jocelyn Maughan.

3. Colour wheel exercise by Jocelyn Maughan from the colour class taught by Phyllis Shillito within the Diploma course at East Sydney Technical College in 1958. "Tertiary" colour wheel with concentric discs representing double-primary, secondary, and nine "tertiary" each represented by eight tones. Collection of Jocelyn Maughan.

4. Colour wheel exercise by Deborah Beck, Meadowbank TAFE, 1973. Fifteen-hue colour wheel very similar to Jocelyn Maughan's Shilltio wheel from 1958, apart from the cadmium yellows in place of chrome and lemon yellow. National Art School Collection.

5. Colour wheel exercise by Deborah Beck, Meadowbank TAFE, 1973. Twelve-hue colour wheel with similar primaries to 3. National Art School Collection.

6. Colour wheel exercise by Deborah Beck, Meadowbank TAFE, 1973. "Tertiary colour wheel", showing "shade, tertiary colour, tint, lighter tint" for nine "tertiary colours" mixed from three mixed secondary colours. National Art School Collection.

7. Colour wheel exercise by Ann Roxburgh, Meadowbank TAFE, 1973. Colour star reminiscent of Itten's design but with 15 hues as in Jocelyn Maughan's 1958 Shillito "No 1" wheel, with the six "warm and cool" primaries repeated in the central disc. National Art School Collection.

8. Colour wheel exercise by student at Hornsby TAFE, 1970s. The diagram closely follows the design of Itten's twelve-hue colour circle from *The Art of Color* (1961). The "secondary" and "tertiary"* colours appear to have been mixed from the three specified primary colours (cadmium [yellow] deep, cadmium red and cerulean blue), and as is inevitable with paints of these hues the resulting purples are very low in chroma. National Art School Collection.

9. Student colour wheel exercise by Rosemary Robins, Hornsby TAFE, 1979. Adaptation of Itten's design to include "warm and cool" versions of each primary colour, and a total of fifteen hues, as in Shillito's "No 1" wheel. The "warm and cool" primaries mix a much greater gamut of colours than the single primaries of diagram 8, largely because of the presence of magenta and cyan subtractive primaries as the "cool" red and "cool" blue respectively. National Art School Collection.

*The historical term "tertiary colour" was introduced by George Field in 1817 with the meaning of greyed colours that in Field's view "contain" all three of the historical "primary colours", red, yellow and blue, and "tertiary" is used in this sense in exhibits 3 and 6. An entirely different usage of "tertiary colour", which dates at least to John Ruskin in 1877, refers to the six third-order hues of a 12-hue "colour wheel", and "tertiary" is used in this sense in exhibit 9. Both conceptions of "tertiary colour" are absent from standard CIE colour terminology, in which greyed object colours are simply said to have low chroma.

Exhibits 1 and 4-9 reproduced by kind permission of NAS archivist Deborah Beck.

Chroma

Chroma: "colourfulness of an area judged as a proportion of the brightness of a similarly illuminated area that appears white or highly transmitting"(CIE, 2011, 17-139).

Chroma is the chromatic strength of an object colour, the perceived amount of difference from a grey of the same lightness (value). The formal definition above is based on the idea that when a chromatic light-reflecting object is increasingly strongly illuminated, the colourfulness of its appearance increases, but the brightness of a similarly illuminated white object increases proportionately, so its intrinsic strength of colour or chroma can be defined as the colourfulness judged relative to this brightness.

Below: 1. Effect on chroma of a difference in amount of bias of spectral reflectance of two yellow artists' paints (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/015.php). 2. Value-chroma chart (below, with tint-shade scales above) by Jocelyn Maughan, used as teaching material at Meadowbank TAFE. Collection of Jocelyn Maughan.

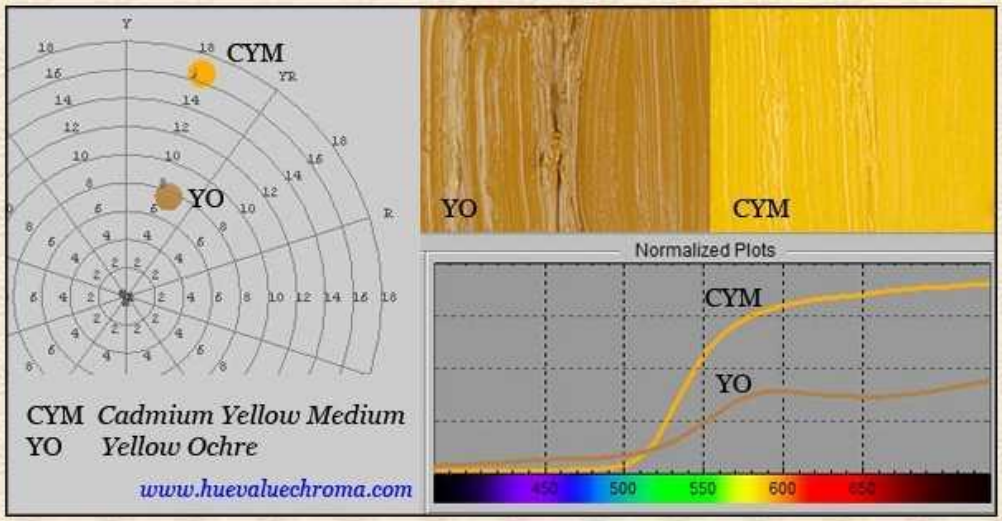
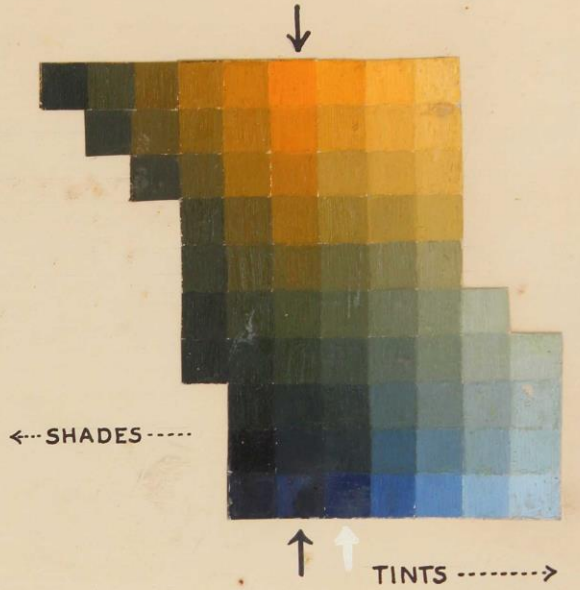
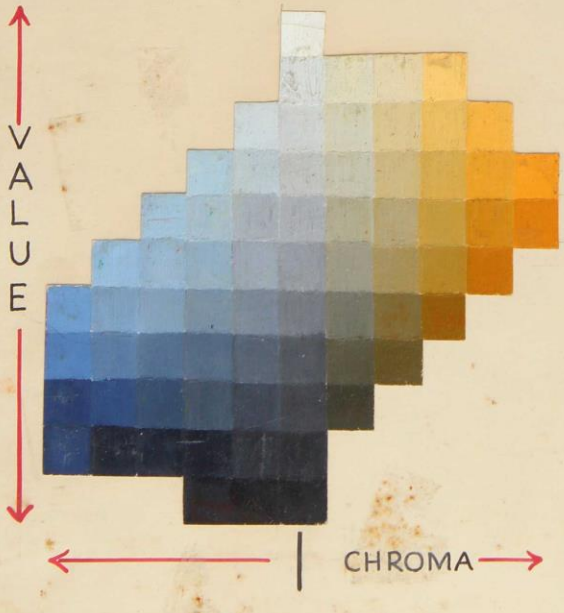


Figure 1.5.3. **Comparison of spectral reflectance curves of a medium- and a high-chroma orange-yellow paint. Munsell plot and spectral reflectance curves for Gamblin Conservation Colours from *drop2color* by Zsolt Kovacs Vajna; paint sample photos from dickblick.com.**

COLOUR

Mixtures of two complementary hues plus tints and shades





Value and chroma change -mixtures with black, white and greys...

Brightness and Colourfulness

Brightness: "attribute of a visual perception according to which an area appears to emit, or reflect, more or less light. NOTE The use of this term is not restricted to primary light sources" (CIE, 2011, 17-111).

Colourfulness: "attribute of a visual perception according to which the perceived colour of an area appears to be more or less chromatic" (CIE, 2011, 17-233).

Consider a stripe of red paint passing between shadow and light. By virtue of the pre-conscious processes that equip our vision with a high degree of *colour constancy*, we instantly, effortlessly and automatically see the stripe as *being* the same colour, that is, as having the same red object colour, over its whole length. This red colour can be specified in terms of an object colour notation such as Munsell hue, value and chroma, and we could confirm that the stripe matches the same Munsell chip placed beside it in the shadow and in the light. Nevertheless, the appearance of the stripe is brighter and more colourful in the light than in the shadow. The colour attributes of brightness and colourfulness pertain to the perceived colour of the light reaching our eyes from different parts of the stripe, rather than to the object colour seen as belonging to the stripe itself. Brightness is how we perceive the amount of light emitted, transmitted or reflected by an area. Colourfulness is how we perceive the absolute amount of spectral bias of a light; it is the cumulative effect of its saturation (q.v.) and brightness.

Below: Demonstration of distinction between lightness and chroma *vs* brightness and colourfulness. David Briggs, *The Dimensions of Colour*, http://www.huevaluechroma.com/016.php).

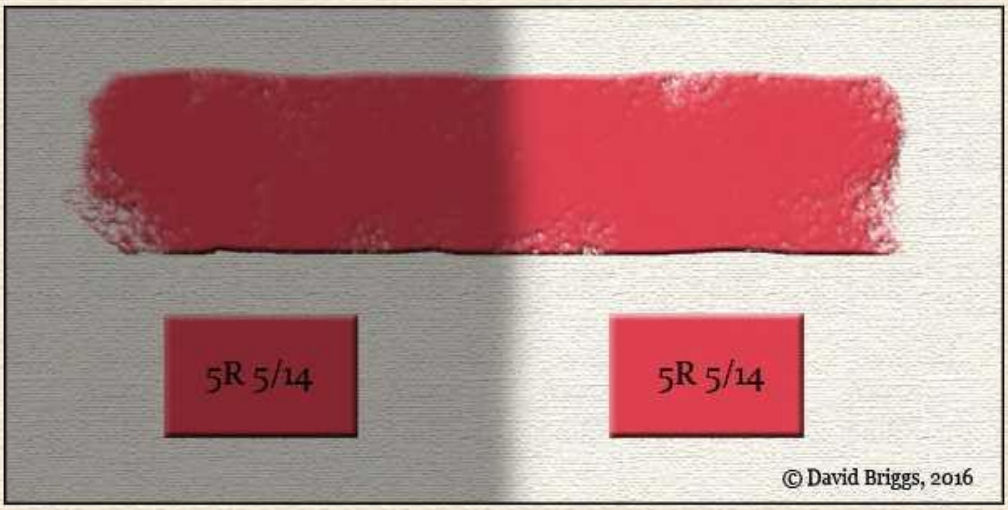


Figure 1.6.1. **Digital painting of a stripe of red paint passing between shadow and light.**

Saturation

Saturation: *"colourfulness of an area judged in proportion to its brightness"* (CIE, 2011, 17-1136).

The word "saturation" is often used loosely for chroma or for some form of relative chroma, but is defined by the CIE as a distinct attribute of perceived colour. For an object colour, saturation is in effect chroma *judged relative to lightness*. In the first diagram below, the dark ruby reds R1 and R2 have lower chroma that R3, but their chroma *relative to their lightness,* or saturation, is similarly high.

On a Munsell hue page, lines of uniform saturation radiate from near the black point, in contrast to the vertical lines of uniform chroma. These lines of uniform saturation are important because they define the colours of a *shading series*, that is, image colours that evoke the appearance of a uniformly coloured diffusely-reflecting object turning under a light source.

Below: 1. Pair of diagrams explaining CIE definition of saturation. 2. Lines of uniform saturation on Munsell hue pages from the Munsell Book of Colour and for digital colours. 3. Demonstration of shading series, that is, lines of uniform saturation (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/017.php).

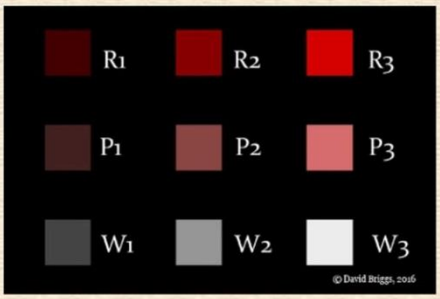


Figure 1.7.1. **Three series of RGB colours each of uniform saturation: R_1-R_3 (high saturation), P_1-P_3 (medium saturation) and W_1-W_3 (zero saturation). Although R_1 and R_3 have the *same saturation*, R_3 is seen as having *higher chroma* than R_1 when viewed in the same context, because by emitting *a greater amount* of equally saturated red light, it is more colourful (but see also Fig. 1.5.2!).**

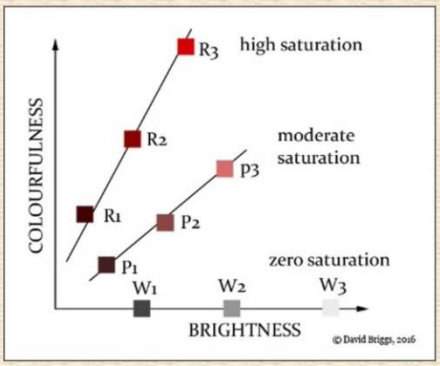


Figure 1.7.2. **Illustration of the CIE definition of saturation. R_1-R_3 have high saturation, P_1-P_3 have moderate saturation and W_1-W_3 have zero saturation.**

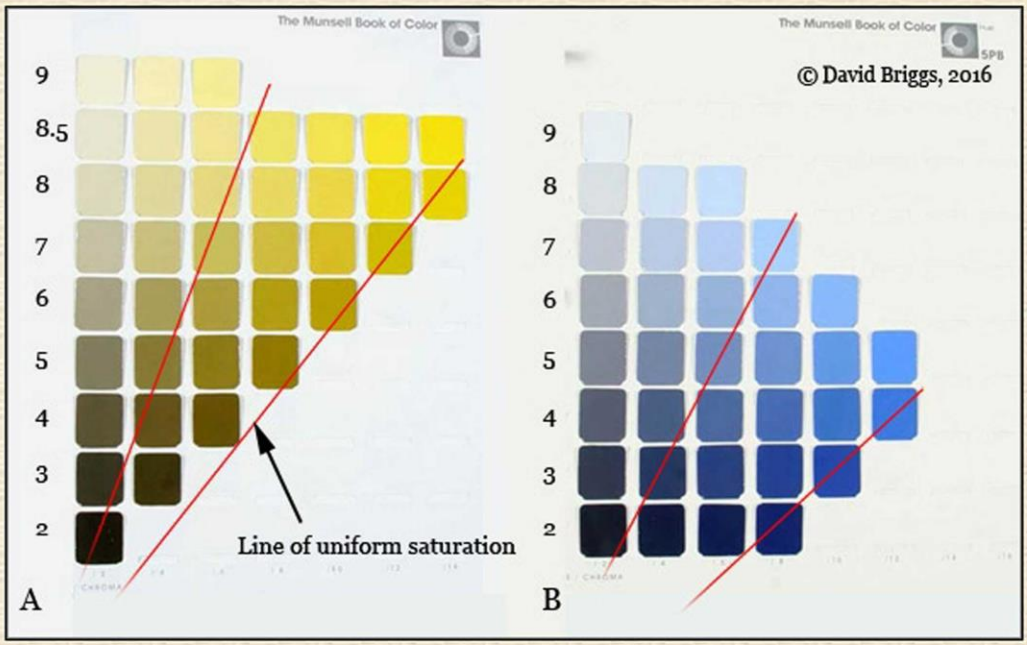


Figure 1.7.3. **Lines of uniform saturation on *Munsell Book of Color*, Glossy Edition (A) 5Y and (B) 5PB hue pages. The 5PB chips attains higher saturation but lower chroma than the 5Y chips.**

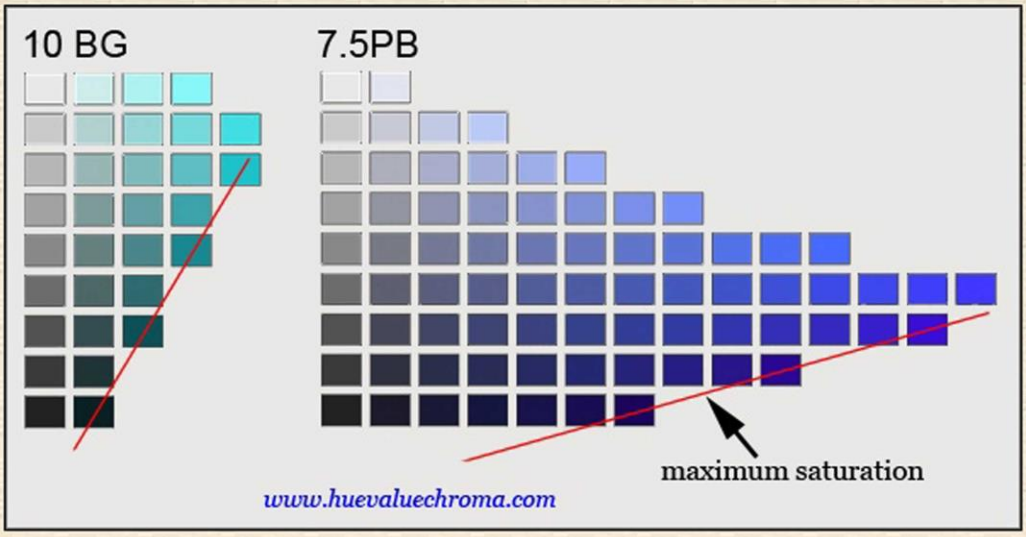


Figure 1.7.5. **Munsell hue pages of digital colours from www.andrewwerth.com/color/. Quantified as chroma relative to lightness, the maximum saturation attained by digital colours of different hues varies greatly.**

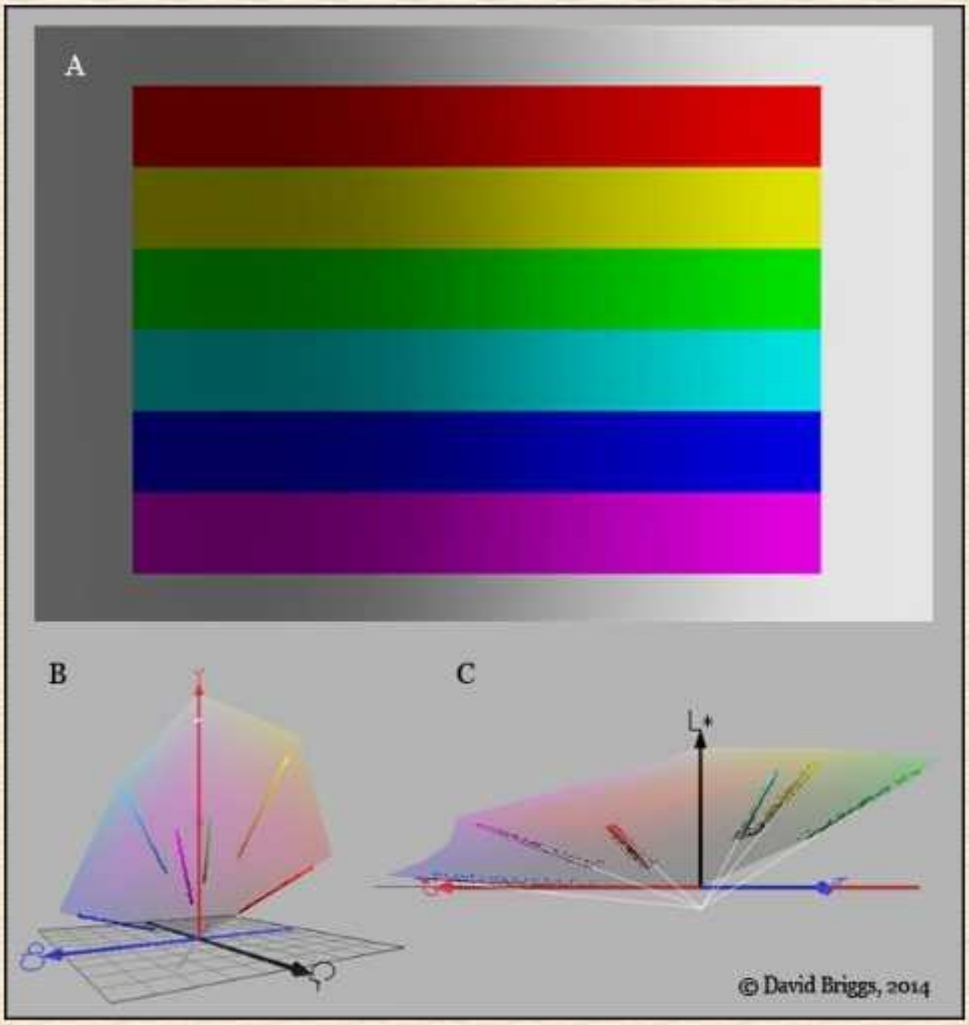


Figure 1.7.4. **A. Seven uniform saturation series (including the achromatic surround) perceived as uniformly coloured objects under varying illumination. David Briggs, 2007, Photoshop CS2. B. Colours from A plotted in YCbCr space. C. Colours from A plotted in L*a*b* space. B and C plotted using the program *Colorspace* by Philippe Colantoni.**

Blackness

Blackness: the perceived amount of black in the [object] colour relative to pure black. A colour with the notation S 2060-Y10R has a blackness value of 20. Colours with the same blackness are found along the straight lines parallel to the side W-C on the NCS Colour Triangle (NCS UK glossary, http://www.ncscolour.co.uk/information/ncs-glossary.html).

The Scandinavian *Natural Colour System* (NCS) and the historically important Ostwald system both use an attribute of perceived object colour, known as *black content* or *blackness*, not currently defined by the CIE. In both systems object colours are considered to be divisible in black, white and full colour components, represented on triangular hue pages that together make up a double-cone space, although in the NCS system this space is only partly filled with colour samples. The NCS differs from the Ostwald system in being based purely on colour perception. Lines of uniform NCS blackness descend obliquely outwards on Munsell hue pages at an angle that varies according to hue.

Below: 1. Diagram of NCS system. 2. Lines of uniform NCS blackness on four Munsell hue pages paints (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/018.php).

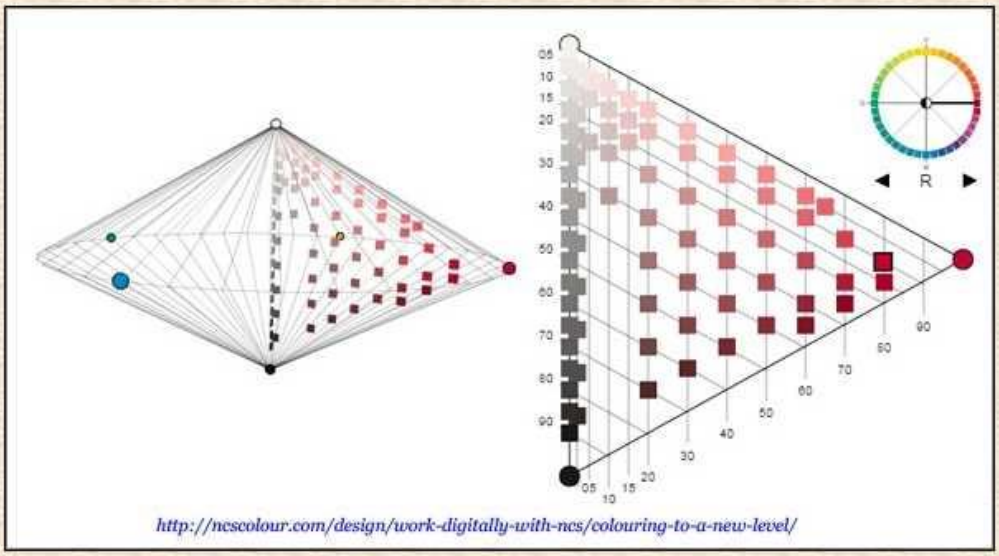


Figure 1.8.3. **Screenshot of the online NCS Navigator, an interactive tool for exploring the NCS system, and for selecting palettes based on constant hue, whiteness, blackness, or chromaticness. This screenshot shows on the left the overall double-cone geometry, which can be tilted at any angle and filled in various ways, and on the right the one of the forty hue pages that can be selected.**

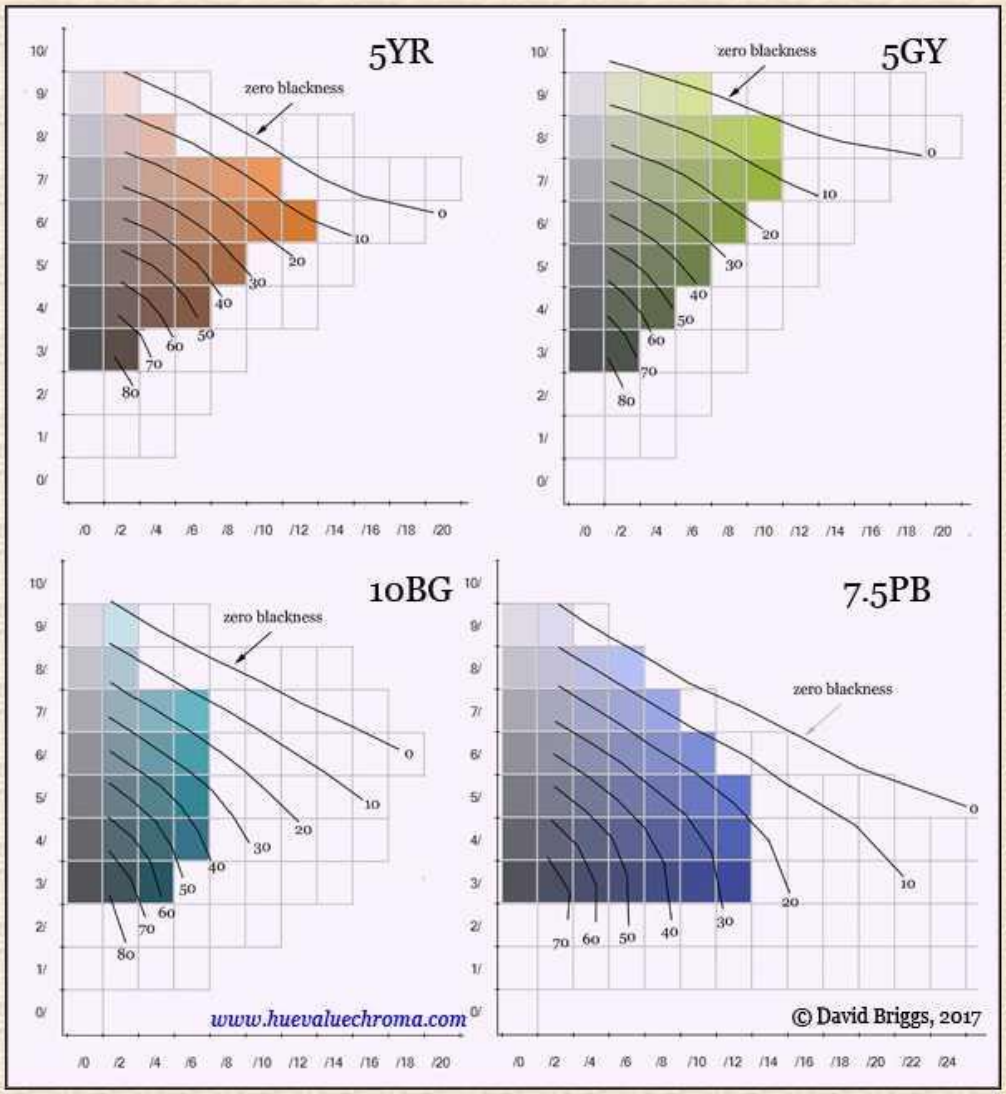


Figure 1.8.4. **Lines of uniform blackness on the NCS Y50R, G50Y, B50G and R50B hue pages, each projected onto the nearest Munsell hue page, 5YR, 5GY, 5BG and 7.5PB respectively (after Billmeyer and Bencuya, 1987). Colours represented in the *Munsell Book of Colour Matte Edition* shown in colour (NCS chips are also matte); limits of optimal colours shown as grey grid.**

Brilliance

Brilliance: *relative brightness of an area judged on a scale proceeding from black through decreasing blackness (or "greyness") to fluorent (fluorescent-looking) and then self-luminous. Brilliance "may be considered negative for grayness and positive for fluorence, or simply continuous from the black point" (Evans, 1974, p. 100).*

In his book *The Perception of Color* (1974) Kodak scientist Ralph Evans introduced the term *brilliance* for a scale from blackness to luminosity. Evans found that for a given surround luminance, a central stimulus below a certain luminance was perceived as being black, and increasing the luminance above this threshold evoked decreasing perceived black content up to a point where the latter disappears. This point of zero black content occurs at varying lightness for stimuli of different hues and different saturations. Increasing the luminance above this level results in the perception of a fluorescent object colour (*fluorence*) and eventually the perception of a light source.

What makes Beau Lotto's remarkable "Cube I" illusion (below) so striking is that the same image colour is perceived as a black-containing object colour and as a highly fluorent or luminous colour in different parts of the image.

Below: 1. Illustration of scale of brilliance: the same three ellipses vary in brilliance in different contexts. 2. In Lotto's cube illusion the same image colour is perceived as a black-containing object colour and as a highly fluorent or luminous colour in different parts of the image (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/018.php).

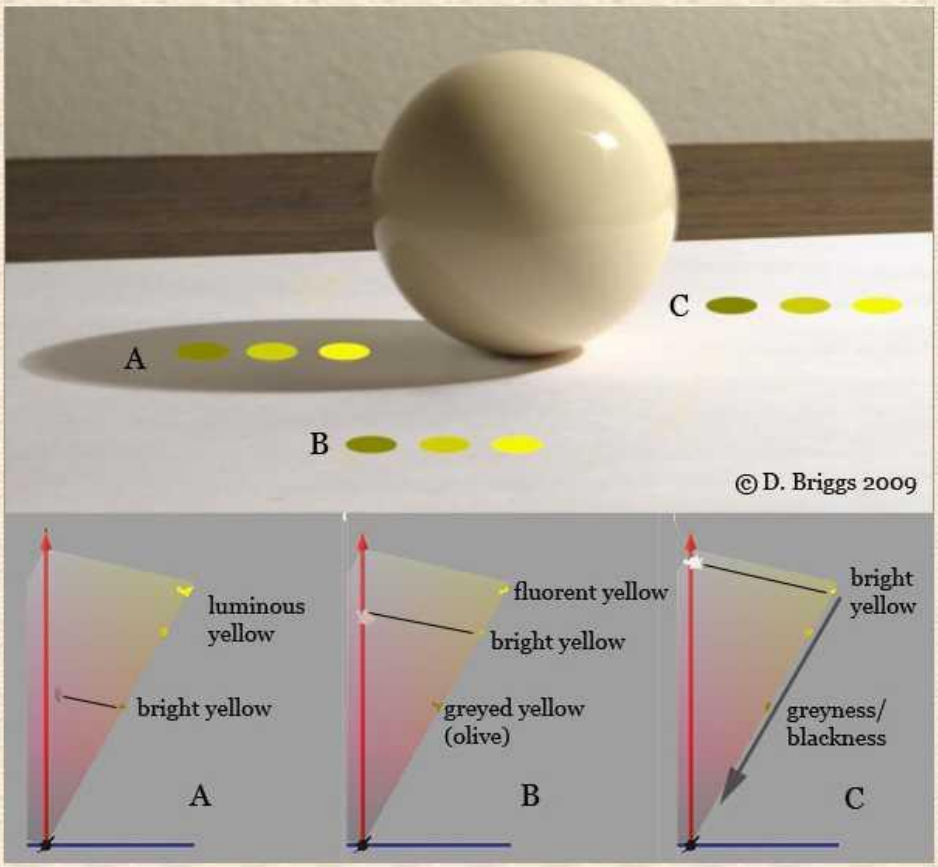


Figure 1.8.7. **Identical sets of three ellipses of varying luminance overlaid on three differently illuminated areas of a photograph. In each case the dot that is close to the brightness of the surrounding white paper looks like a bright or zero-blackness yellow dot; the less luminant dots look olive-coloured, and the more luminant dots look fluorent or luminous.**

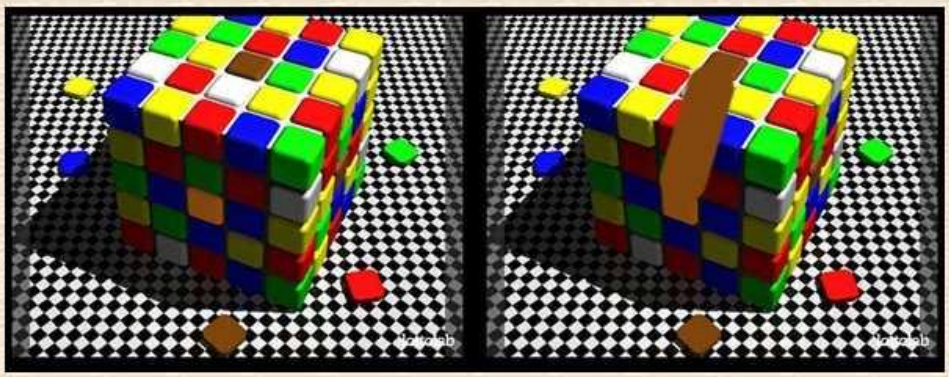


Figure 1.8.10. **Beau Lotto's cube illusion. A video of this illusion can be downloaded as "Cube I" from http://www.labofmisfits.com/downloads.asp. Characteristically, Lotto's video caption "See identical tiles differently" conflates image properties with depicted object properties: the tiles "exist" only as perceived objects in the scene depicted in the image; it is the *rhomboidal areas of the image* that are physically identical. We find the blackish brown and fluorent orange object colours seen as belonging to those perceived tiles so visually insistent that we literally cannot *see*, that is, *direct our attention to*, the similarity of the image colours until we break the representational spell of the image by joining up the areas or (as in the video) by masking the rest of the image.**

PART 3: APPLIED COLOUR

In this section we illustrate a miscellany of terms relating to the scientific, technical and aesthetic aspects of colour practice. We are grateful to be able to include student exercises and teaching materials associated with the history of the National Art School illustrating various subjective concepts of colour design. Materials from the National Art School Collection are reproduced by kind permission of NAS archivist Deborah Beck.

Colour Space

Colour space: geometric representation of colour in space, usually of 3 dimensions (CIE, 2011, 17-226).

Below: 1. Comparison of gamut (colour range) of an artists' acrylic paint range with sRGB colour space. image, David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/015.php.

2. A standard digital colour space (*sRGB*) represented in various colour spaces. David Briggs (in press, from Chapter 8, *Colour Spaces* in the *Routledge Handbook of Philosophy of Colour*.

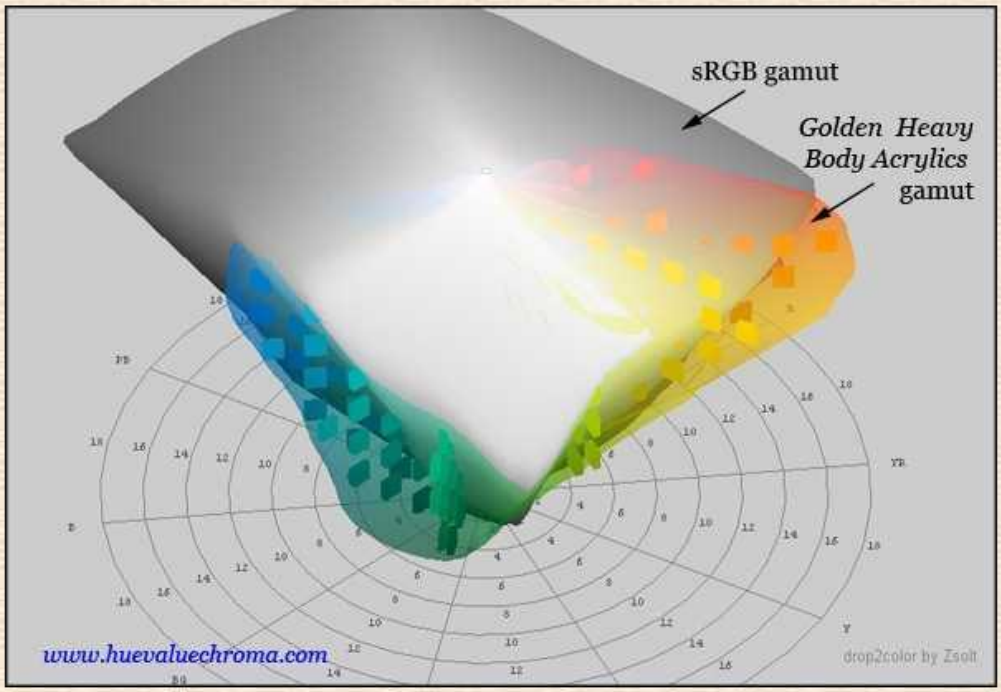
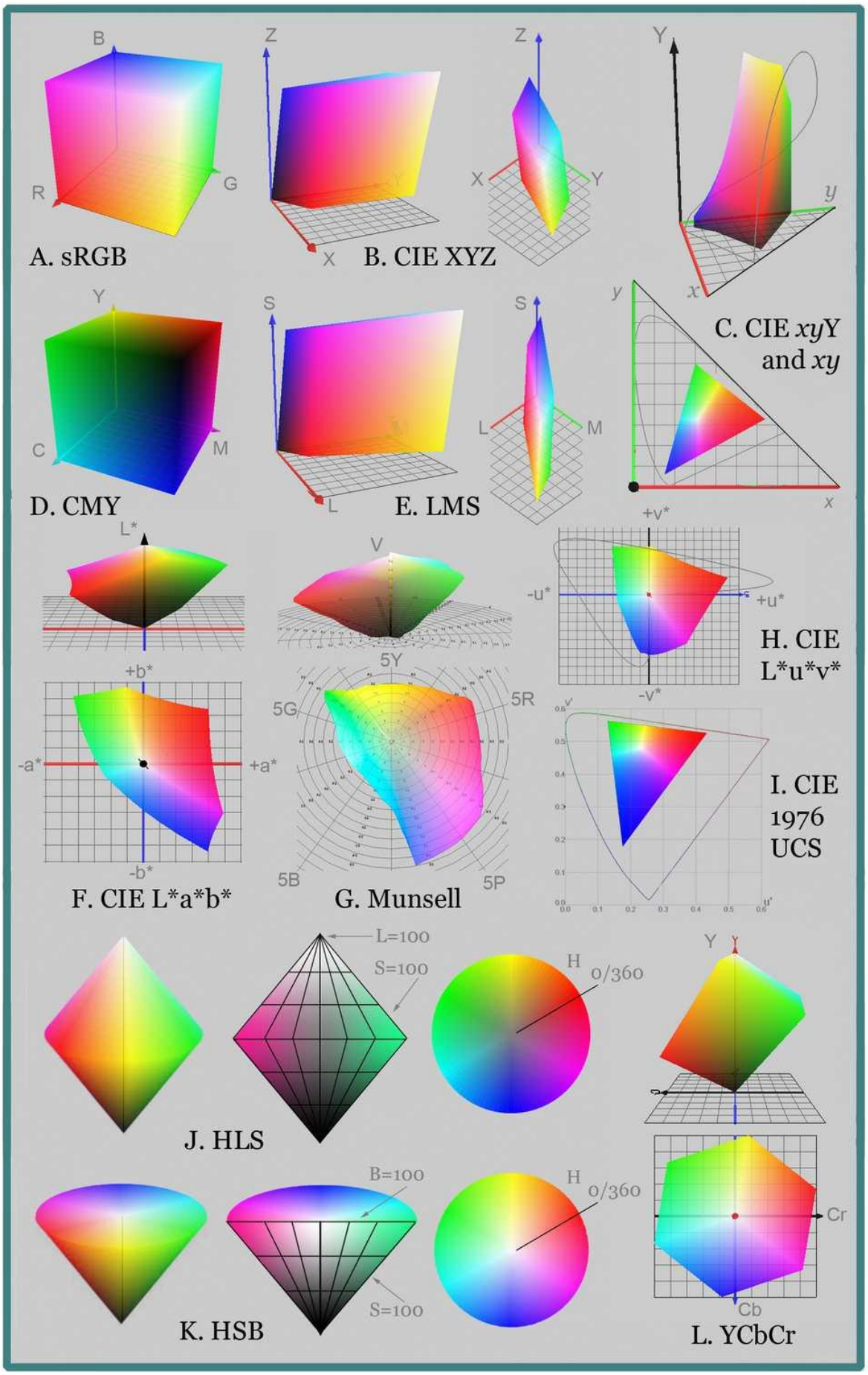


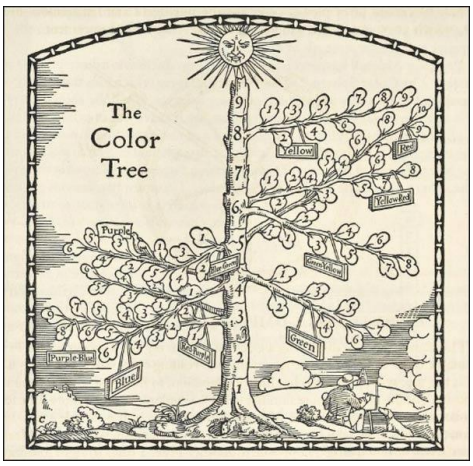
Figure 1.5.8. **Comparison of gamut of a range of artists' acrylic paints (in colour) with that of standard sRGB digital colours (in grey). The paints (*Golden Heavy Body Acrylics*) exceed the gamut of RGB colours in the areas where the latter is relatively poor (around yellow and cyan), thanks to the presence containing a good range of cadmium colours plus two phthalocyanine greens (blue shade and yellow shade) and a phthalocyanine blue.**


B
R
G
A. sRGB
Z
X
B. CIE XYZ
Z
X
Y
Y
y
x
C. CIE xyY
and xy
y
x
Y
C
M
D. CMY
S
L
E. LMS
S
L
M
L*
+b*
-a*
+a*
-b*
F. CIE L*a*b*
V
5Y
5G
5R
5B
5P
G. Munsell
+v*
-u*
+u*
-v*
H. CIE
L*u*v*
I. CIE
1976
UCS
L=100
S=100
H
0/360
J. HLS
Y
B=100
S=100
H
0/360
K. HSB
Cr
Cb
L. YCbCr

Munsell System

Munsell system: system for specifying object colours in terms of perceptually even scales of *hue* (Munsell hue) *lightness* (Munsell value) and *chroma* (Munsell chroma), invented by the artist and art teacher Albert Munsell in the early 20th century.

Below: 1 On left, response to the concept of a tree of colours by Helen Coates-Milton and other students in the *Visual Dictionary of Colour* workshop, 2017, and on right, model of Munsell colour space, Nina Price, Lilly Marshall, Clayton Croker, Samuel Briant and Jess Amos, from same workshop. 2. Another view of the model of Munsell colour space. 3. Munsell hue circle exercises by Tony Tuckson, Sydney Technical College, 1947-49. National Art School Collection.



Cleland's illustration of Munsell's conception of his system as a tree of colours (T. M. Cleland, 1921, *A practical description of the Munsell color system*.

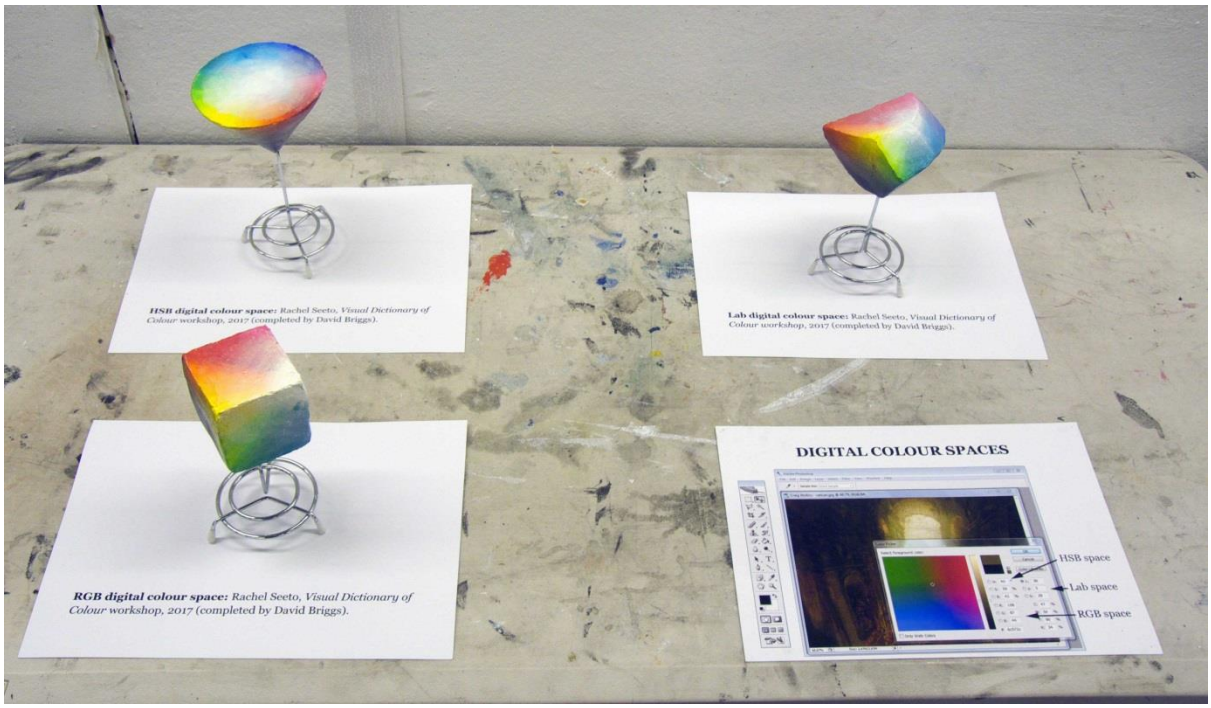
Digital Colour Spaces

RGB: cubic digital colour space specifying colours according to relative red, green and blue components, usually on a nonlinear scale.

HSB: digital colour space classifying RGB colours according to hue angle (H), relative saturation (S) and relative brightness (B).

CIE L*a*b* colour space: three-dimensional, approximately uniform colour space produced by plotting in rectangular coordinates L* (CIE lightness) and a* and b* (chromatic coordinates corresponding roughly to redness/greenness and yellowness/blueness respectively). A version of CIE L*a*b* called Lab space is of central importance in Photoshop.

Below : Models of RGB, HSB and Lab digital colour space in air-drying clay by Rachel Seeto, *Visual Dictionary of Colour workshop*, 2017 (painted by David Briggs).

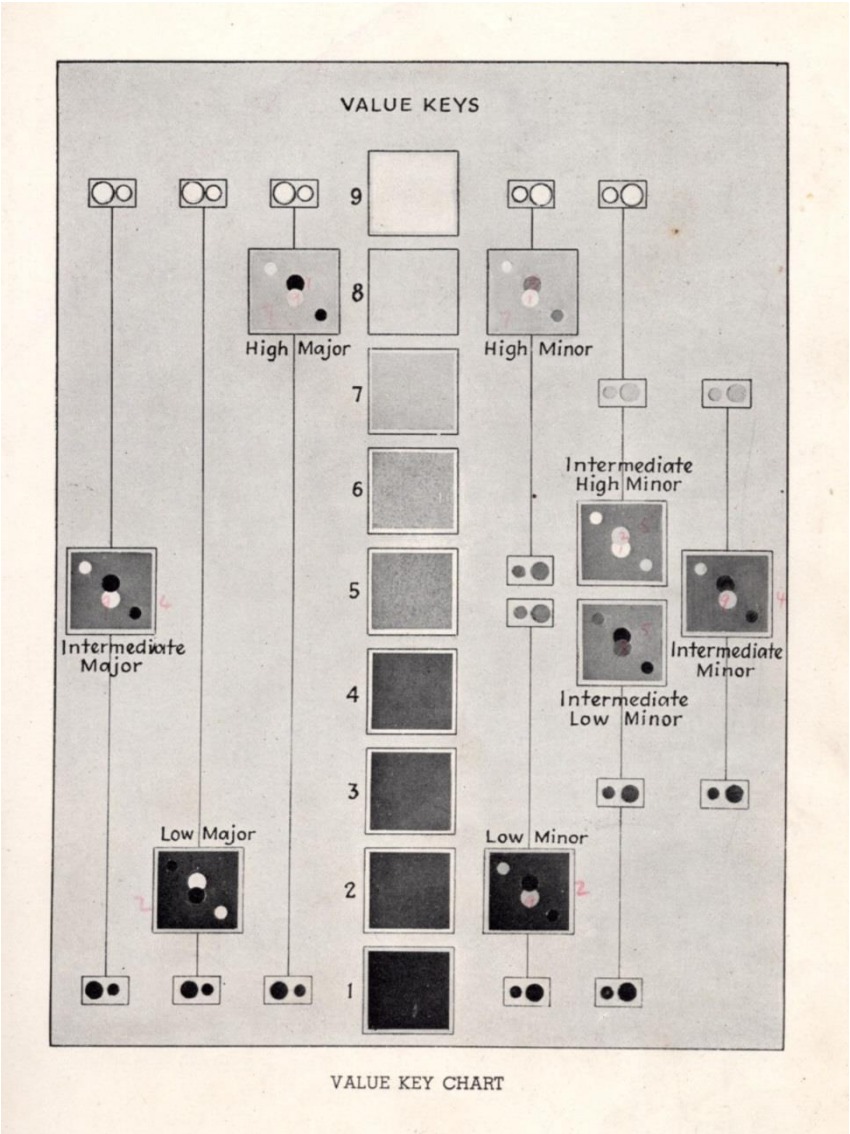


Value Key

Low key: “A composition in which the dominant [Munsell] value is approximately 1, 2 or 3” (Graves, 1941, *The Art of Color and Design*, p. 281).

Intermediate key: “A composition in which the dominant [Munsell] value is approximately 4, 5 or 6” (Graves, 1941, *The Art of Color and Design*, p. 281).

High key: “A composition in which the general or prevailing tonality or dominant value is approximately [Munsell value] 7, 8 or 9” (Graves, 1941, *The Art of Color and Design*, p. 280).



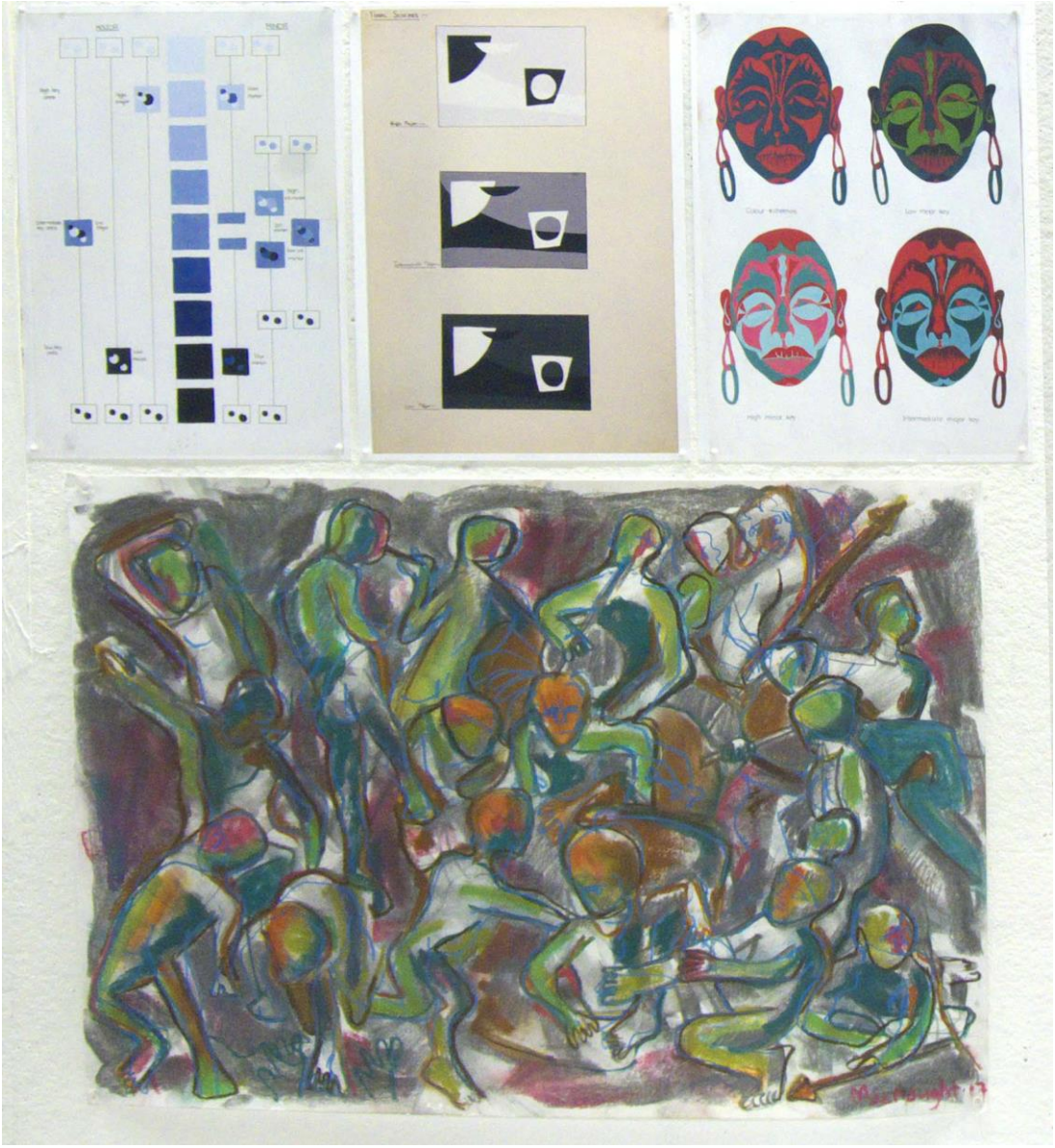
Maitland Graves, 1941, *The Art of Color and Design*, p. 137. The value scale is a nine-value Munsell scale.

Value Interval

Major: “Large or great interval, strong contrast, such as between values that are 5, 6 or 7 [Munsell value] steps apart” (Graves, 1941, *The Art of Color and Design*, p. 281).

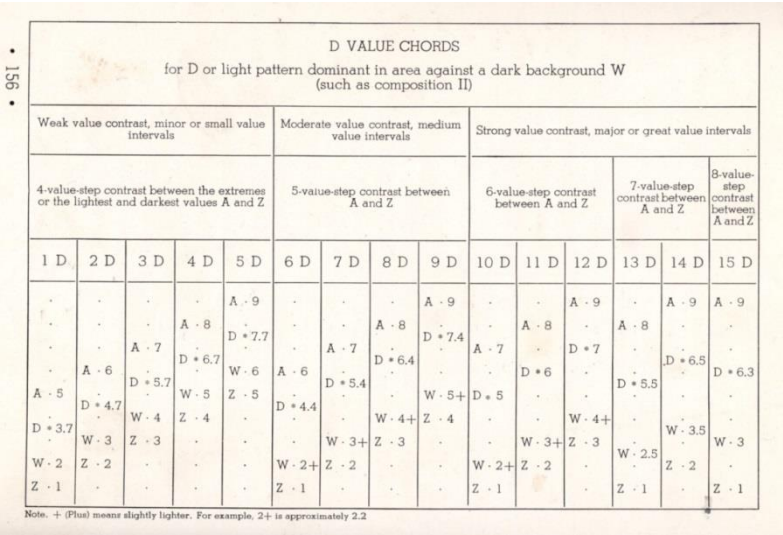
Minor: “Small interval, closed up, muted. Subdued, muffled or weak contrast such as between values that are three [Munsell value] steps apart or less” (Graves, 1941, *The Art of Color and Design*, p. 282).

Below: 1. Value key and value interval chart exercise by Deborah Beck for the colour course taught at Meadowbank TAFE in 1973. 2. Value key and interval composition exercise by a student from the colour course at Hornsby TAFE in the 1970s. 3. Value key and interval composition exercise by Ann Roxburgh from the colour course at Meadowbank TAFE in the 1970s. 1-3 Collection of National Art School. 4. Value key and interval composition exercise (intermediate minor) by Kim Macnaught, *Visual Dictionary of Colour* workshop, 2017.



Value Chord

Value chord: “A value combination in which the values and the intervals between the values or the value rhythm is planned according to the principles of design. This term distinguishes such an organized value relationship from a value combination in which the Value Rhythm is not so planned” (Graves, 1941, *The Art of Color and Design*, p. 285).



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D VALUE CHORDS

for D or light pattern dominant in area against a dark background W (such as composition II)

Weak value contrast, minor or small value intervals					Moderate value contrast, medium value intervals				Strong value contrast, major or great value intervals					
4-value-step contrast between the extremes or the lightest and darkest values A and Z					5-value-step contrast between A and Z				6-value-step contrast between A and Z			7-value-step contrast between A and Z		8-value-step contrast between A and Z
1 D	2 D	3 D	4 D	5 D	6 D	7 D	8 D	9 D	10 D	11 D	12 D	13 D	14 D	15 D
·	·	·	·	A · 9	·	·	·	A · 9	·	·	A · 9	·	A · 9	A · 9
·	·	·	A · 8	·	·	·	A · 8	·	·	A · 8	·	A · 8	·	·
·	·	A · 7	·	D * 7.7	·	A · 7	·	D * 7.4	A · 7	·	D * 7	·	·	·
·	A · 6	·	D * 6.7	·	A · 6	·	D * 6.4	·	·	D * 6	·	·	D * 6.5	D * 6.3
A · 5	·	D * 5.7	·	W · 6	·	D * 5.4	·	·	D * 5	·	·	D * 5.5	·	·
·	D * 4.7	·	W · 5	Z · 5	D * 4.4	·	·	W · 5+	·	·	W · 4+	·	·	·
D * 3.7	·	W · 4	Z · 4	·	·	·	W · 4+	Z · 4	·	·	Z · 3	·	W · 3.5	W · 3
·	W · 3	Z · 3	·	·	·	W · 3+	Z · 3	·	·	W · 3+	·	W · 2.5	·	·
W · 2	Z · 2	·	·	·	W · 2+	Z · 2	·	·	W · 2+	Z · 2	·	·	Z · 2	·
Z · 1	·	·	·	·	Z · 1	·	·	·	Z · 1	·	·	Z · 1	·	Z · 1

Note. + (Plus) means slightly lighter. For example, 2+ is approximately 2.2

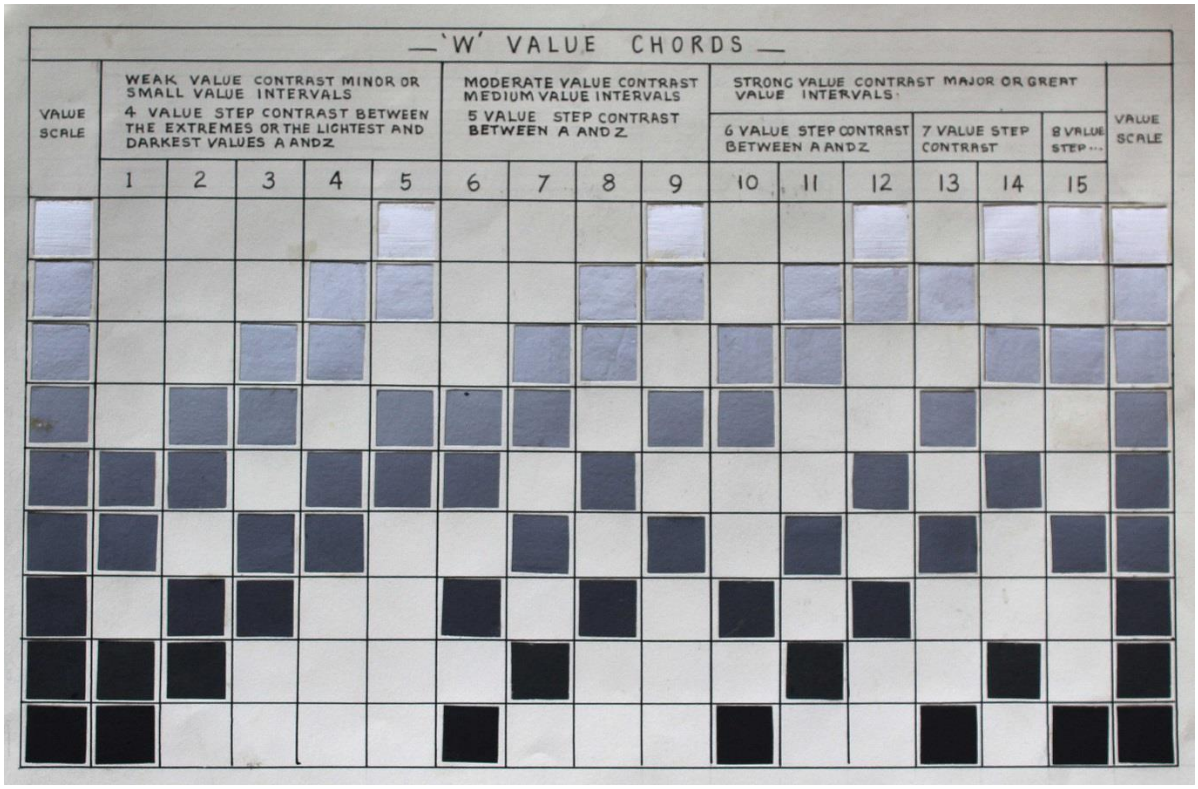
Maitland Graves, 1941, *The Art of Color and Design*, p. 156. The value scale is a nine-value Munsell scale.

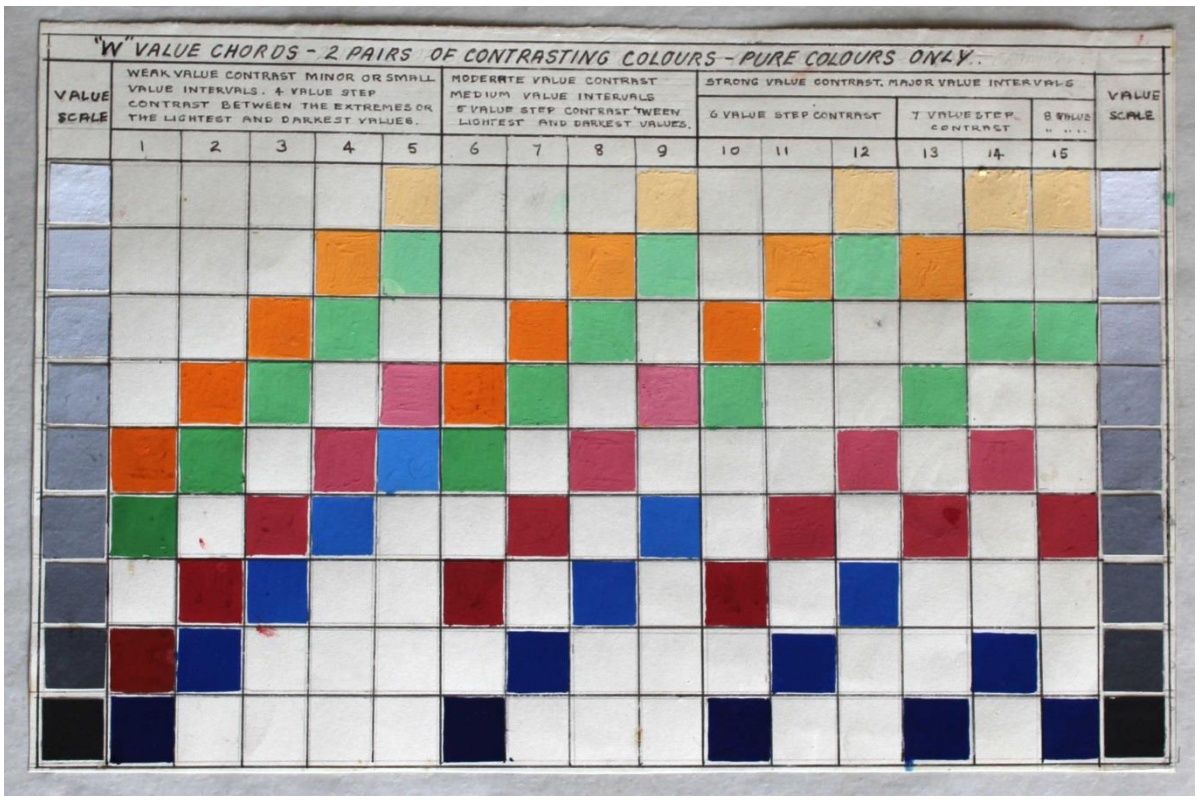
Colour Chord

Colour chord: “A colour combination in which the colors and the intervals between the colours, or the color rhythm, is planned according to the principles of design. This term distinguishes such an organized color relationship from a color combination in which the Color Rhythm is not so planned” (Graves, 1941, *The Art of Color and Design*, p. 285).

The colour course taught by Phyllis Shillito at the East Sydney Technical College included exercises in value chords and colour chords that closely follow diagrams from Maitland Graves’ book *The Art of Color and Design* (1941, 1951). These concepts had also been emphasized in the first decades of the twentieth century by Denman Ross and his former student Arthur Pope.

Below: 1, Value chord and 2, colour chord exercises by Jocelyn Maughan from the colour course taught by Phyllis Shillito within the Diploma course at the East Sydney Technical College in 1958. Collection of Jocelyn Maughan.


— 'W' VALUE CHORDS —
VALUE SCALE
WEAK VALUE CONTRAST MINOR OR SMALL VALUE INTERVALS
4 VALUE STEP CONTRAST BETWEEN THE EXTREMES OR THE LIGHTEST AND DARKEST VALUES A AND Z
MODERATE VALUE CONTRAST MEDIUM VALUE INTERVALS
5 VALUE STEP CONTRAST BETWEEN A AND Z
STRONG VALUE CONTRAST MAJOR OR GREAT VALUE INTERVALS:
6 VALUE STEP CONTRAST BETWEEN A AND Z
7 VALUE STEP CONTRAST
8 VALUE STEP...
VALUE SCALE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

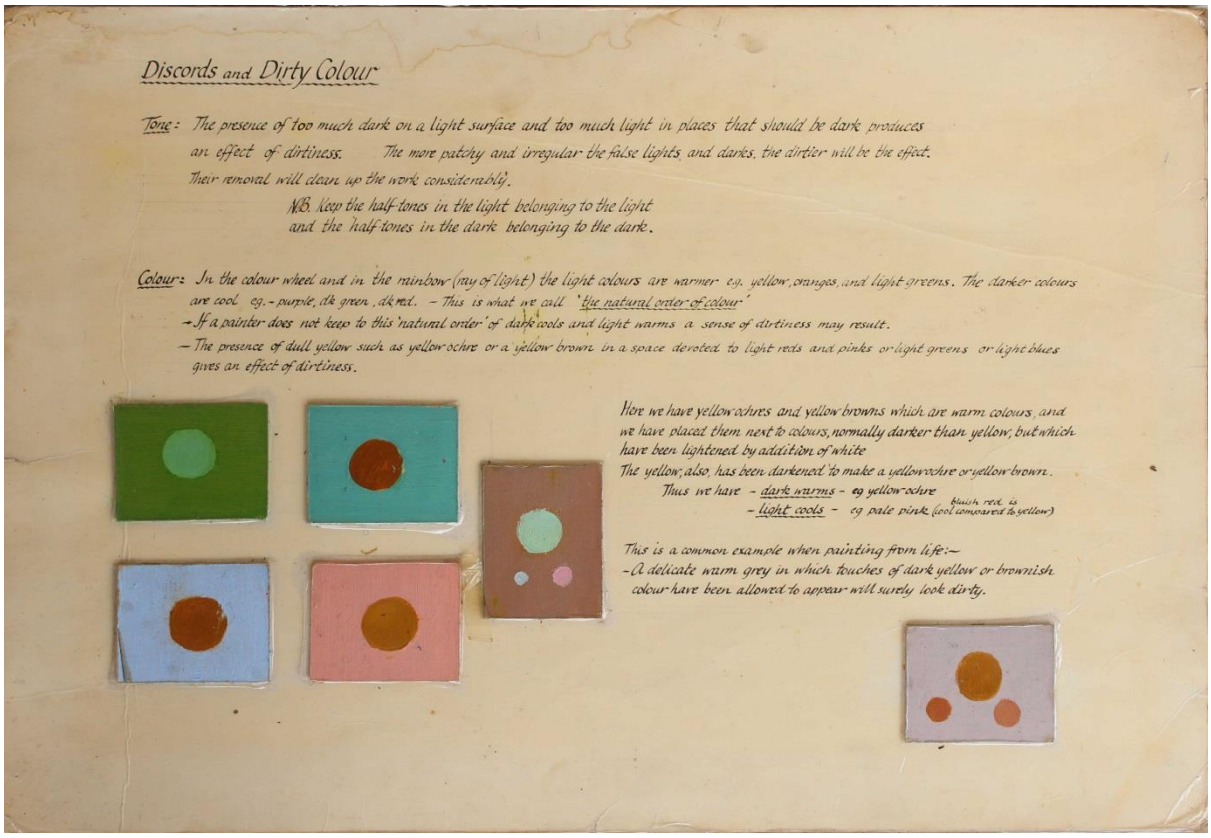

"W" VALUE CHORDS - 2 PAIRS OF CONTRASTING COLOURS - PURE COLOURS ONLY.
VALUE SCALE
WEAK VALUE CONTRAST MINOR OR SMALL VALUE INTERVALS. 4 VALUE STEP CONTRAST BETWEEN THE EXTREMES OR THE LIGHTEST AND DARKEST VALUES.
MODERATE VALUE CONTRAST MEDIUM VALUE INTERVALS 5 VALUE STEP CONTRAST 'TWEEN LIGHTEST AND DARKEST VALUES.
STRONG VALUE CONTRAST. MAJOR VALUE INTERVALS
6 VALUE STEP CONTRAST
7 VALUE STEP CONTRAST
8 VALUE
VALUE SCALE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Discord

1. “Extreme contrast or opposition” (Maitland Graves, 1941, *The Art of Color and Design*, p. 279).

2. “reversal of the natural order” of colours (H. Barrett Carpenter, Suggestions for the Study of Colour, 1915). “Reversal” here refers to the order of values representing different hues relative to the order of values of their “full” colour versions; Carpenter considers such reversals “unendurable” in large quantities but to add much to brilliance in small quantities.

Below: Teaching materials on discords (in second sense) by Jocelyn Maughan, Meadowbank TAFE. Collection of Jocelyn Maughan.



Monochromatic, Analogous and Complementary Colour Schemes

Monochromatic, analogous and complementary colour schemes feature widely in systems of “colour harmony”, the most important early source being Chevreul.

172. Hence we infer that there are six distinct harmonies of colour, comprised in two species.

First Species—Harmonies of Analogy.—1. *The harmony of scale*, produced by the simultaneous view of different tones of the same scale, more or less approximating. 2. *The harmony of hues*, produced by the simultaneous view of tones of the same, or nearly of the same depth, belonging to neighbouring scales. 3. *The harmony of a dominant coloured light*, produced by the simultaneous view of various colours assorted according to the law of contrast, but one of them predominating as would result from the view of these colours through a slightly-coloured glass.

173. Second Species—Harmonies of Contrast.—1. *The harmony of contrast of scale*, produced by the simultaneous view of two very distant tones of the same scale. 2. *The harmony of contrast of hues*, produced by the simultaneous view of tones of different depths, belonging to neighbouring scales. 3. *The harmony of contrast of colours*, produced by the simultaneous view of colours, belonging to very distant scales, assorted according to the law of contrast. The difference in the depth of the adjacent tones may further augment the contrast of colours.

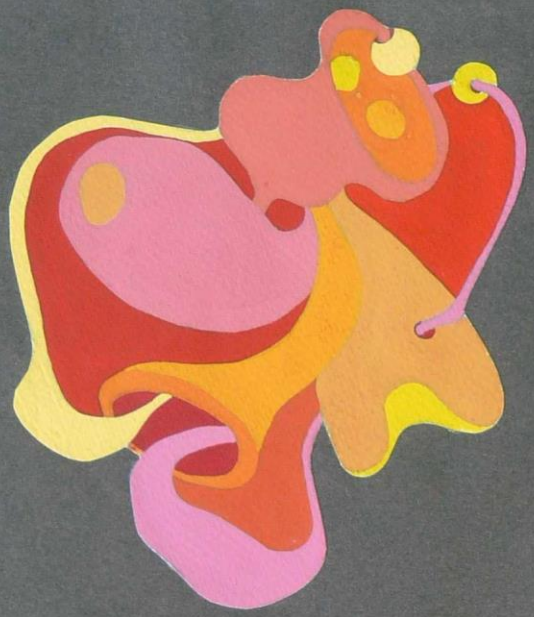
Chevreul [tr. Spanton, 1857], *The Laws of Contrast of Colour*.

Triadic and Tetradic Schemes

Symmetrical triadic and tetradic colour schemes also feature in various “colour harmony” systems, and seems to derive ultimately from the suggestion by Ogden Rood that “colours less than 80 or 90 degrees apart suffer from harmful contrast, while those more distant help each other” (*Modern Chromatics*, 1879, p. 292).

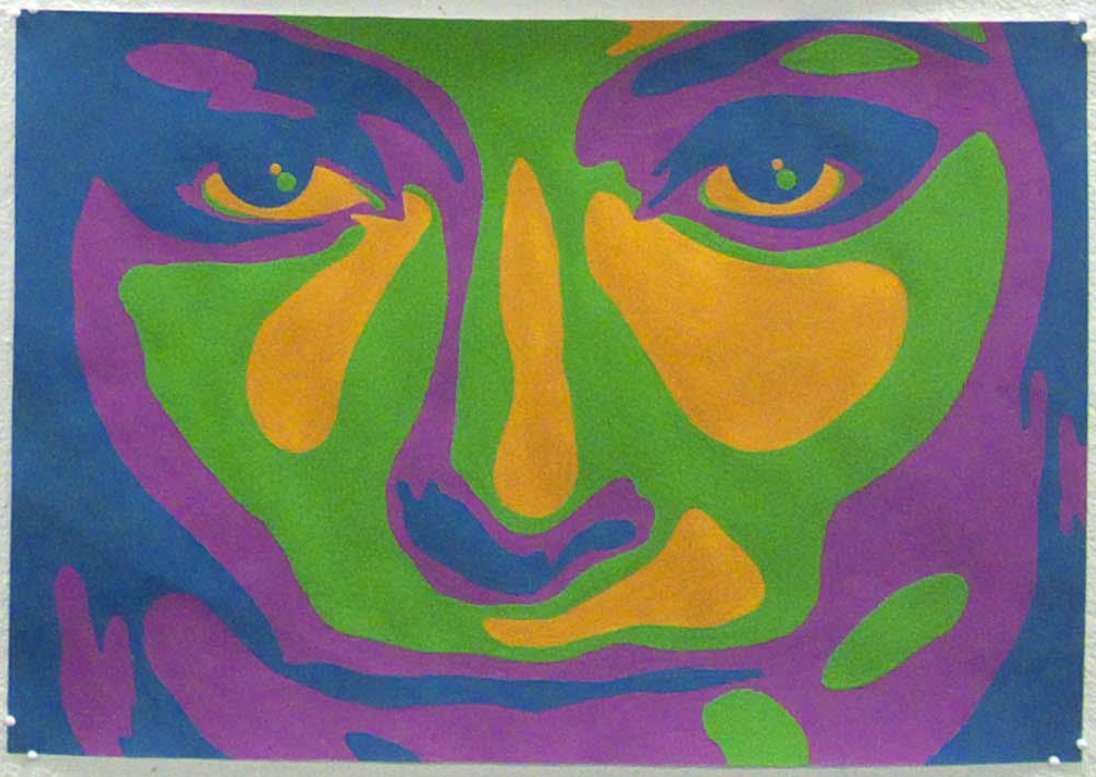
Below: Triadic and tetradic colour schemes used in exhibits 3 and 4 below in Munsell 40-hue circle.

Next two pages: 1, 2, Abstract compositions using analogous and complementary (“Harmonious” and “Contrasting”) hue schemes, Ann Roxburgh from the colour course at Meadowbank TAFE in the 1970s. Collection of National Art School. 3. Abstract composition using triadic hue scheme. 4. Figurative composition based on tetradic hue scheme. Maria Constantinescu, *Visual Dictionary of Colour* workshop, 2017.



Harmonious hues with one used as a discord

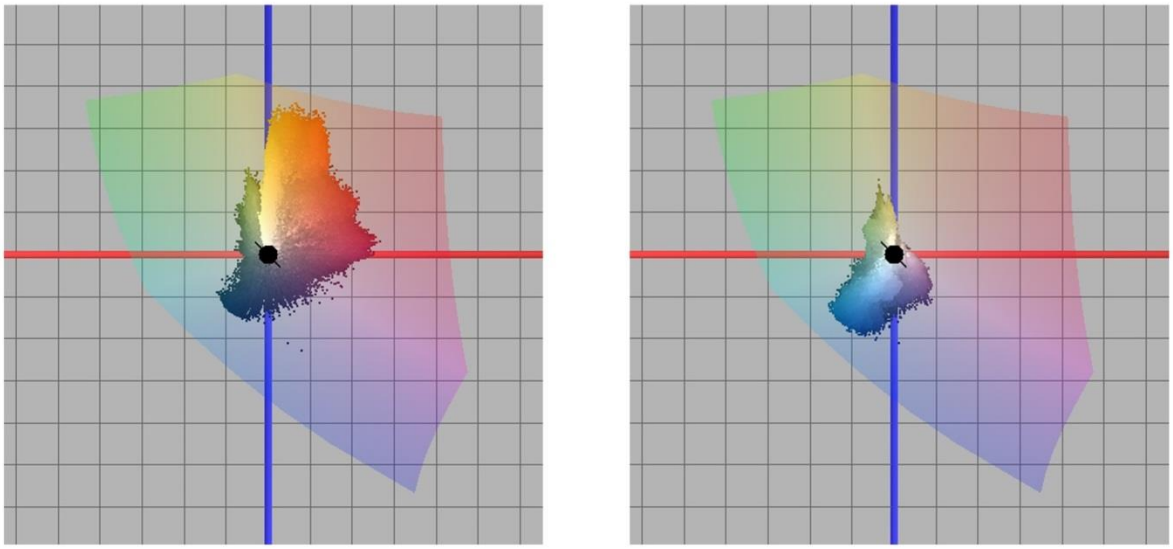
Contrasting hues with an associated discord.



Restricted Gamut

A restricted gamut automatically results from mixing all colours from a limited palette consisting of a very small number of colourants (often three), especially if these are far from the ideal subtractive primaries.

Below: 1. Two student design exercises, possibly by Rose Vickers, East Sydney Technical College, 1962. Collection of National Art School. 2. RGB colours from photographs of 1, plotted in CIE*L*a*b* space.



NCS Nuance

Nuance: “a colour's relationship to black and to maximum colour intensity or chromaticness. The other element needed to describe a colour would be the hue. Colours that have the same nuance but a different hue will be found in exactly the same location of the NCS Colour Triangle” (*NCS UK glossary*, http://www.ncscolour.co.uk/information/ncs-glossary.html).

A concept of “colour harmony” associated with the historical Ostwald system and the modern Scandinavian Natural Colour System is that of unity of “nuance” in these systems, that is equality of black, white and colour content for different hues (see *Blackness*). In addition to the unity imparted by their shared black/ white/ chromatic content, such sets of colours maintain the relative lightness relationships shown by the full colours of each hue (yellow lightest, etc.). Sets of colours related in this way have long been labelled a "concord", in contrast to a "discord" (*q.v*) where the "natural order" of lightness of the different hues is disrupted.

Below: Comparison of colour set of identical “nuance” with set of identical value and chroma (David Briggs, *The Dimensions of Colour*, www.huevaluechroma.com/018.php).

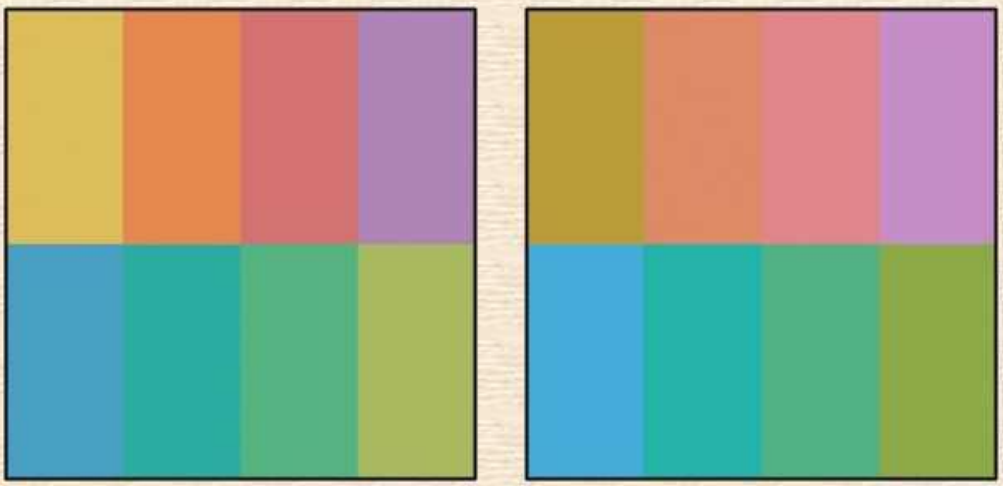


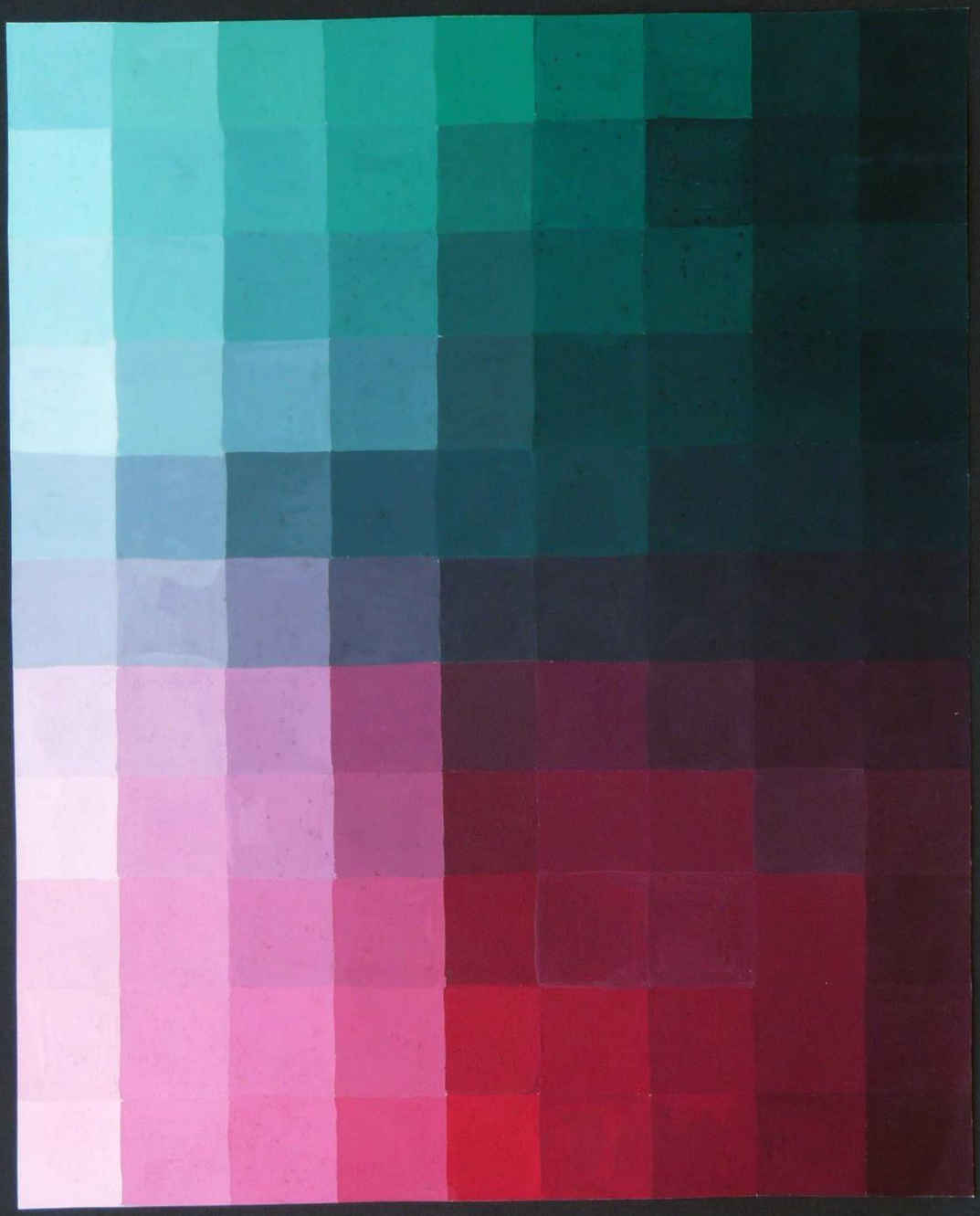
Figure 1.8.6. A. Eight colour swatches of identical NCS blackness (30) and chromaticness (30) from the *NCS Digital Colour Atlas 1950* (2007). B. Eight colour swatches of identical lightness and chroma, with hues similar to, and Munsell value and chroma close to the average of, the swatches in A. After an experiment by Green-Armytage (2006).

Tints and Shades

Tint: object colour perceived to consist of a pure colour plus white, without any black content.

Shade: object colour perceived to consist of pure colour plus black, without any white content.

Below: 1. Tint-shade scale by Rose Espinosa, *Visual Dictionary of Colour* workshop, 2017. 2. Exercise in tints and shades of progressive mixtures of two paint-mixing complementaries. Student exercise by Deborah Beck for the colour course taught at Meadowbank TAFE in 1973. Collection of National Art School.



Green + carmine mixed together in gradual steps. Each step mixed with white + then each step mixed with black.

Washes and Glazes

Wash: Layer of colourant applied with a flowing, liquid consistency. Washes are the dominant mode of watercolour application and may be built up in many superimposed layers.

Glaze: generally "a thin transparent layer of oil color of a darker value applied over either an opaque or transparent layer of oil or tempera underpainting of a lighter value" (Mayer, 1991, *The Artist's Handbook of Materials and Techniques*, Fifth edition).

Below: Demonstration of superimposed watercolour washes, Peta Minnici, *Visual Dictionary of Colour* workshop, 2017.

Subtractive Mixing

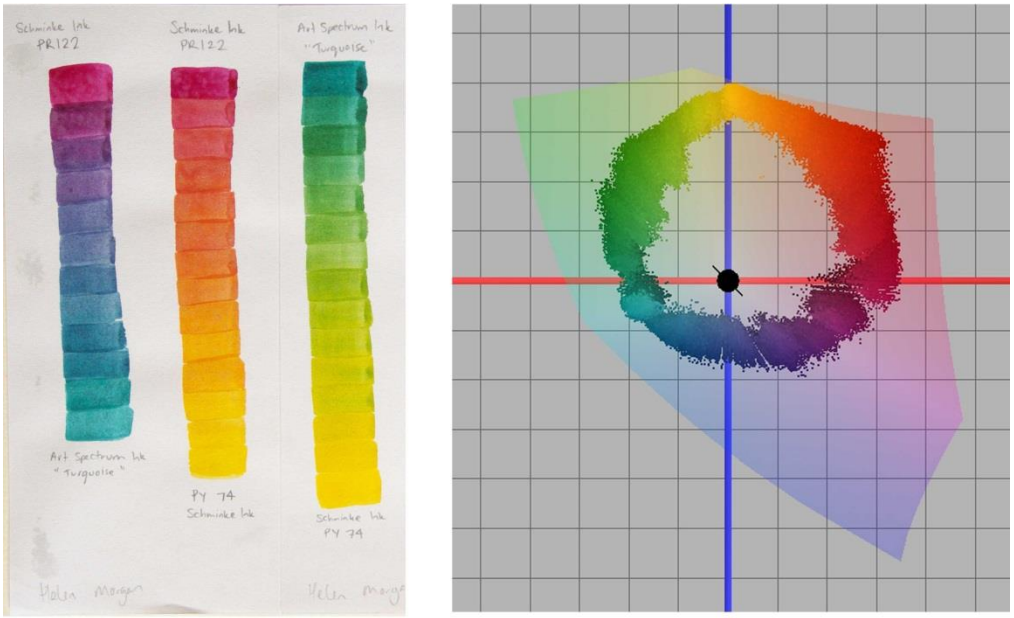
Subtractive mixing: “colour mixing” (strictly, colour stimulus synthesis) “brought about by the transmission of light through two or more superimposed transparent or semitransparent colorants” (Burnham, Hanes and Bartelson, 1957, *Color: a Guide to Basic Facts and Concepts*).

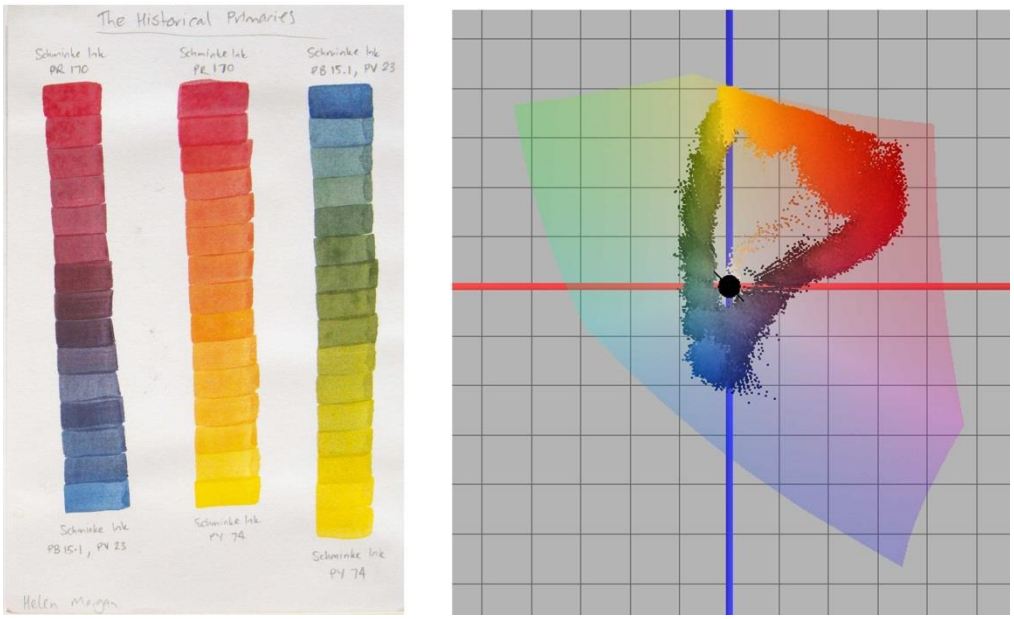
Below: Demonstration of subtractive mixing of superimposed crimson and blue watercolour washes, Peta Minnici, *Visual Dictionary of Colour* workshop, 2017.

Subtractive Primary Hues

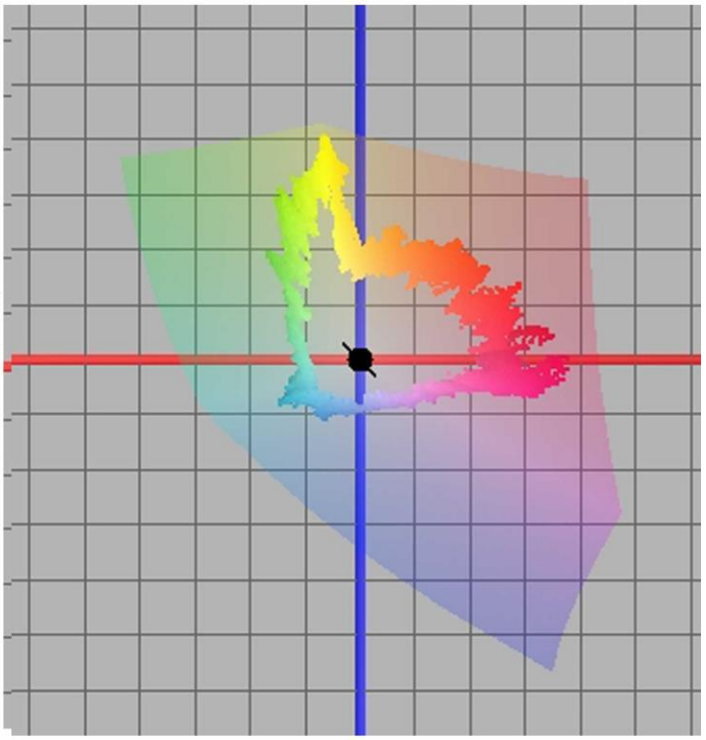
Subtractive primary hues: Optimal hues for mixing a large gamut of colours in processes primarily involving subtractive mixing, including physical intermixture of paints and superimposition of transparent colourants (glazes and washes). Colourants close to yellow, magenta and cyan are optimal for such processes in all media.

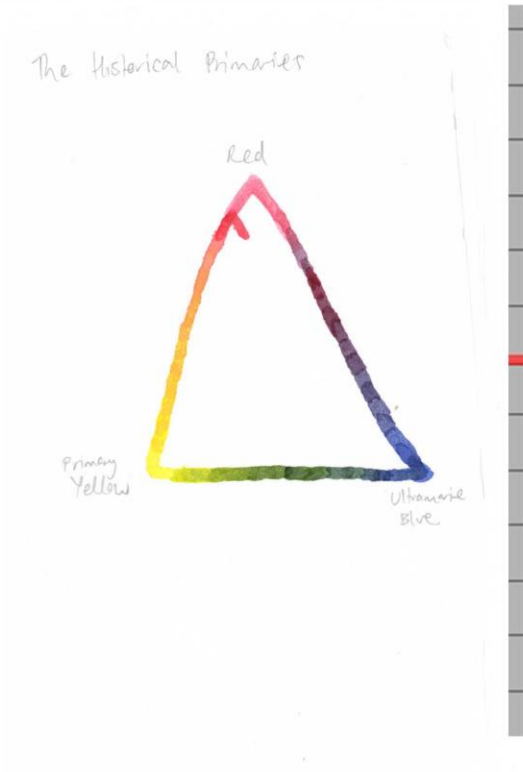
Below: 1. Comparison of gamut of cyan, magenta and yellow pigmented inks with gamut of inks of the historical "primary" hues (red, blue and yellow). Diagrams on right show ranges of photographed colours in CIE L*a*b* colour space; some ink colours near yellow are beyond the RGB gamut of the photograph and so are clipped. Helen Morgan, *Visual Dictionary of Colour* workshop, 2017. 2. Similar comparison to 1, using artists' watercolours. Helen Morgan, *Visual Dictionary of Colour* workshop, 2017.

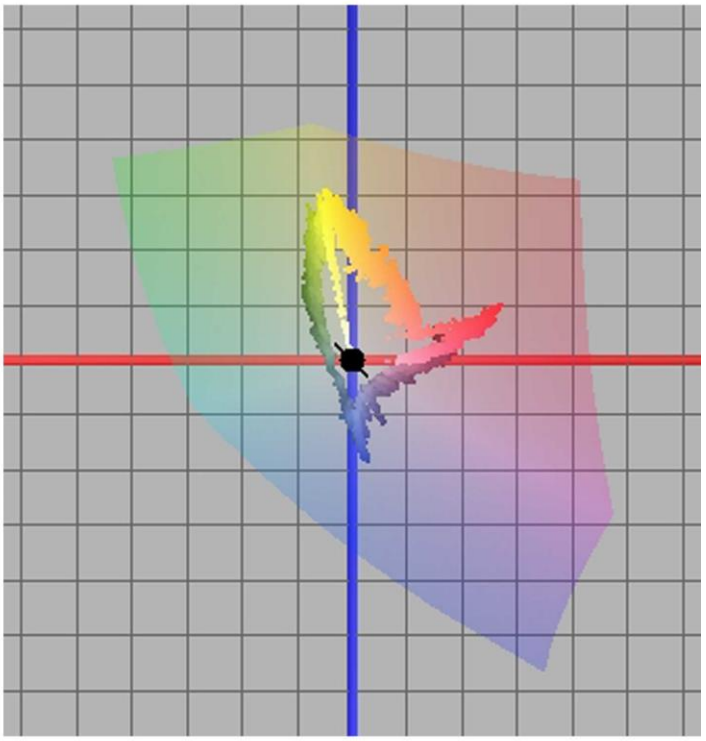





The Subtractive Primaries
magenta
turquoise
primary yellow
Helen Morgan



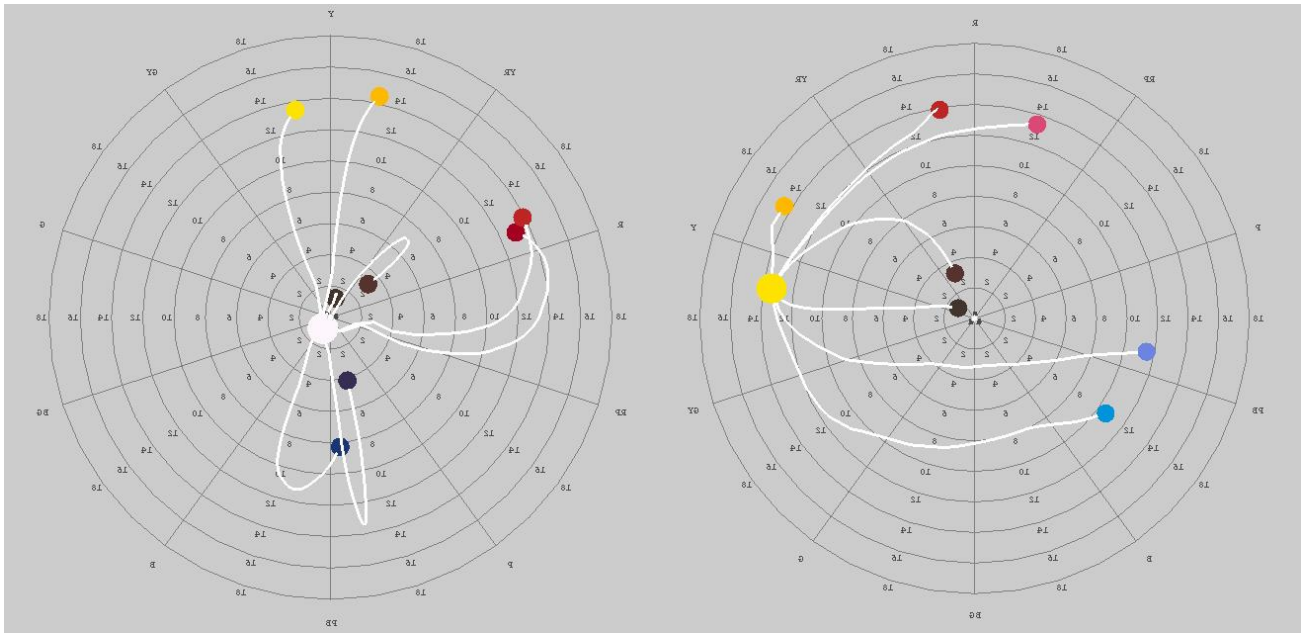

The Historical Primaries
Red
Primary Yellow
Ultramarine Blive

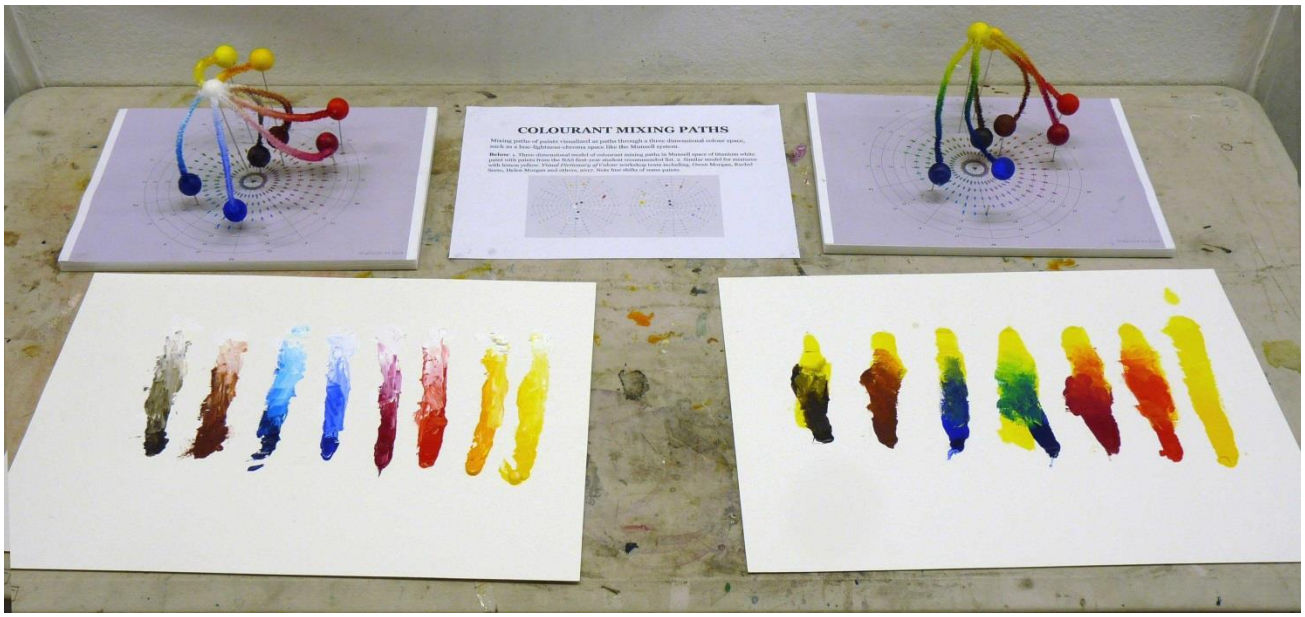


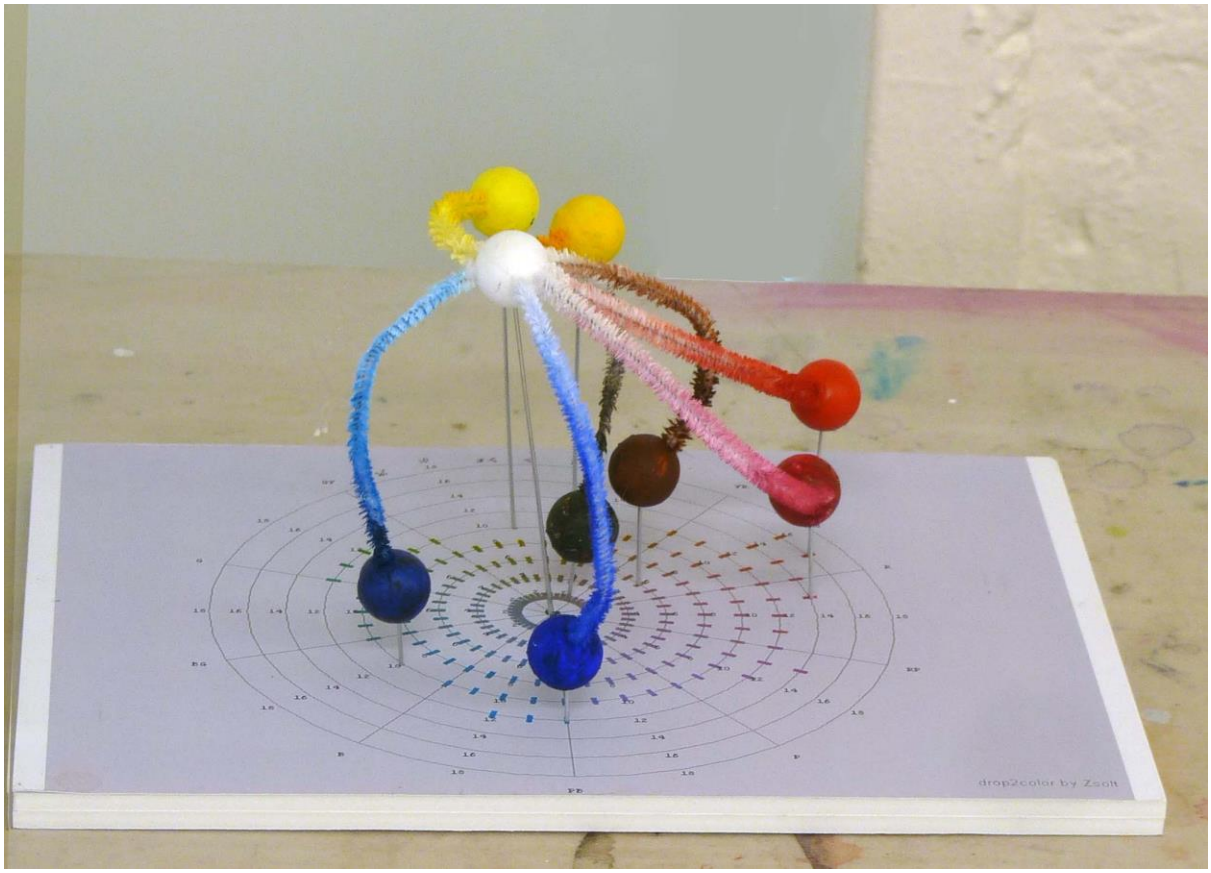
Colourant Mixing Paths

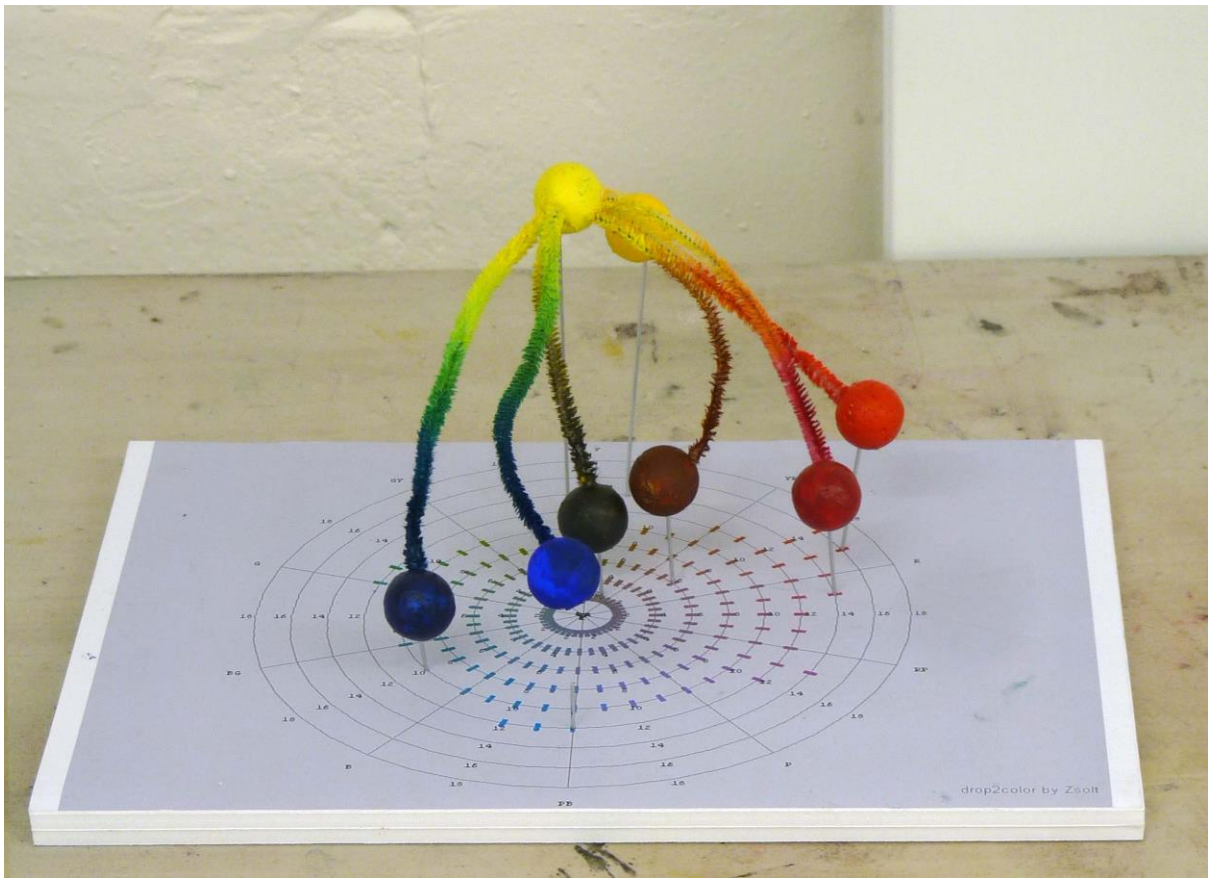
Mixing paths of paints visualized as paths through a three dimensional colour space, such as a hue-lightness-chroma space like the Munsell system.

Below: 1. Predicted colourant mixing paths for white and yellow acrylic paints calculated using the program *drop2color* by Zsolt Kovacs. Note hue shifts of some paints. 2. Three-dimensional model of colourant mixing paths in Munsell space of titanium white paint (left) and lemon yellow (right) with other paints from the NAS first-year student recommended list. 3, 4. Detailed views of models. *Visual Dictionary of Colour* workshop team including, Owen Morgan, Rachel Seeto, Helen Morgan and others, 2017.






drop2color by Zsolt


drop2color by Zsolt

PART 4: HISTORICAL STUDENT EXERCISES FROM THE NATIONAL ART SCHOOL ARCHIVE

Back row, colour theory exercises, left to right:

1. Munsell hue circle exercises by Tony Tuckson, Sydney Technical College, 1947-49.

2. "Green grid", student colour theory exercise by Tony Tuckson, Sydney Technical College, 1947-49.

3. Colour wheel exercise by Ann Roxburgh, Meadowbank TAFE, 1973. Colour star reminiscent of Itten's design but with 15 hues as in Jocelyn Maughan's 1958 Shillito "No 1" wheel, with the six "warm and cool" primaries repeated in the central disc.

4. Colour wheel exercise by Ann Roxburgh, Meadowbank TAFE, 1973. "Tertiary Colour Wheel + Tints & Shades".

5. Colour wheel exercise by student at Hornsby TAFE, 1970s. The diagram closely follows the design of Itten's twelve-hue colour circle from *The Art of Color* (1961). The "secondary" and "tertiary"* colours appear to have been mixed from the three specified primary colours (cadmium [yellow] deep, cadmium red and cerulean blue), and as is inevitable with paints of these hues the resulting purples are very low in chroma.

6. Student colour wheel exercise by Rosemary Robins, Hornsby TAFE, 1979. Adaptation of Itten's design to include "warm and cool" versions of each primary colour, and a total of fifteen hues, as in Shillito's "No 1" wheel. The "warm and cool" primaries mix a much greater gamut of colours than the single primaries of diagram 5, largely because of the presence of a magenta subtractive primary as the "cool" red.

Front row, colour and design exercises, left to right:

1. Student design exercise by Jean Weir, Sydney Technical College, 1948.

2. Student design exercise by Miriam Deen, East Sydney Technical College, 1970s.

3, 4. Two student design exercises, possibly by Rose Vickers, East Sydney Technical College, 1962.

5. Student design exercise by J. Cox, Hornsby TAFE, 1970s.

6. Student design exercise Ann Roxburgh, Meadowbank TAFE, 1973.

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