Chapter 2
The Colour Attributes of Paintings

Abstract In order to understand a phenomenon, one must be able to navigate it: to name its parts and to know its up from its down. Colour is a great challenge in this respect, being dimensionally very complex. This chapter examines the ways in which colour is understood in the visual art domain. Of particular focus is contrast and the many forms that it takes. Firstly, we examine RYB, HSL and other colour spaces and describe the role that they played in our work. We also detail the work of Johannes Itten (1888-1967) whose writings on colour contrast informed a lot of our research. A painter’s colour-thinking is high-level, addressing the structure-based contrast properties of a painting. This structure takes many forms: per region, per object, as a whole across the entire painting, between regions and objects, etc. These we describe and exemplify. We also address the role that they played in our research. The so-called colour harmony describes as high-level principles the difference between ‘good’ and ‘bad’ colour contrasts. We detail historical and contemporary ideas on the subject, much of which has its roots in the work of early twentieth-century mystics. Using this work as a starting point, and the work of the Impressionist painters as reference, we offer our own simple rules of hue harmony.

Keywords Colour harmony · Contrast · Colour theory

2.1 Painters, Paint and Colour Systems

In the engineering domain, the image attributes of a digital colour image are generally understood through the Red, Green and Blue (RGB) values of its pixels. These are known as the photometric attributes of an image. In the art domain, photometrication is less straightforward, requiring reference to multiple systems.

Painters are particularly familiar with the physical property of paint. Paint is composed of a binder (essentially a glue), an extender (to give bulk) and the pigment. It is the pigment that supplies the colour to the paint. The name of the pigment may be derived from the name of the element or compound from which it is derived.
(e.g. cadmium red), from a natural object which embodies that colour (e.g. lemon yellow) or practically anything else (such as Payne’s Grey, named after the artist William Payne). Each paint has different physical properties (drying times, glossiness, etc.), different behaviour (e.g. alizarin crimson is dark when applied thickly, but lighter when applied thinly) and different cost (emerald green used to be made from emeralds).

From artist to artist, there is a huge amount of variance in what particular paints are employed. This variance is across time (some pigments being unavailable before the modern era) [12], and also differs from artist to artist [6] (e.g. some artists favour a more saturated pallet than others).

The painter organises these paints according to their position in the red, yellow and blue (RYB) hue wheel (otherwise known as the ‘painter’s’ hue wheel). The particular spatial ordering of the colours around the RYB wheel serves as a reference point from which particular colour mixes and juxtapositions may be derived. The hue, saturation and lightness (HSL) colour space offers a different organization framework that is more perceptually-based.

Hence, an artist considers paint in a manner that is informed by chemistry, physics and physiology. Dimensionally complex indeed! Colour can also be understood in abstract terms: as a set of descriptive coordinates.

2.2 Colour Spaces

It was Sir Isaac Newton (1643–1727) who first visually organised colour as values within a circle (i.e. a ‘colour wheel’) [23]. A colour wheel expresses unique hues as discrete ‘pie slices’ within a wheel. The colour wheel is spatially limited, being unable to simultaneously accommodate a graduation from fully saturated to black as well as from fully saturated to white. Addressing this limitation, in 1810 the German artist Phillip Otto Runge (1777–1810) described in a letter to Johann Wolfgang Goethe (1749–1832) a system of defining colour as values within a sphere [25]. Runge’s colour sphere (shown in Fig. 2.1) expressed variations in hue across the circumference of the sphere and variations in lightness and saturation across its latitudinal axis, with black at its north pole, and white at the south. This was the first colour space, being a volume within which colour values may be defined.

Contemporary colour spaces serve the same general purpose as Runge’s, yet are organised in different ways and call upon different colour dimensions. Each being a volume, they are all employ at least three values (i.e. three-dimensional cartesian coordinates).

**RYB colour space.** Red, yellow and blue (RYB) is the traditional painter’s colour space. In this space, colour is defined as the selective absorption (i.e. subtraction) of different parts of the colour spectrum. For this reason, it is known as a subtractive space. Though all possible colours may be in theory defined by the three subtractive primaries, in practice white and black are usually added as separate pigments. The RYB colour wheel is different to the RGB colour wheel for the colour complimentary pairs that define it. This difference is shown in Fig. 2.2 where within the RYB wheel,
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Fig. 2.1 Runge’s colour sphere

Fig. 2.2 a The RYB colour wheel. b The RGB colour wheel. Note the difference of complimentary colour pairs

the complimentary of red is green, while within the RGB wheel, the complimentary of red is cyan. The red/green, yellow/purple and blue/orange complimentary pairs are perceptually defined, being ‘retto contrario’ (It. ‘exactly opposite’). Admixes of the RGB complimentary pairs produce neutral greys. In our work, RYB colour space is referenced when we wish to define a colour according to its perpetual complimentary.
RGB colour space. Red, green and blue (RGB) is an additive colour space, wherein different colours are defined by different admixtures of light. This colour space is used in digital imaging and image display devices. A variant of RGB space, known as sRGB, is used in many digital image formats. The colour model is shown in Fig. 2.3. Human vision employs a colour model similar to RGB [14] and is defined by the relative sensitivity of eye cells to these hues. Despite this, RGB is not suitable for describing colours for the purpose of human interpretation. For that, HSL or HSV colour spaces are far more suitable. In our work, images are read-in and written-out in RGB colour space.

HSL colour spaces. Hue, saturation and value (HSV) or Hue, saturation and lightness (HSL) are the three distinct perceptual attributes of colour, with hue and saturation being together its chromatic component. They are far more human-readable than RGB or any other colour model [18] and are the standard point of reference for artists and designers when they conceptualise their colour thinking. They are particularly suitable for digital artists, as the HSL values may be digitally ‘dialled up’ or ‘dialled down’, something that is not possible in traditional painting.

- **Lightness** is the perceived intensity of a colour. It occupies a uniquely important position in the colour triumvirate, being self-sufficient from chromaticity. In other words, it is easy to imagine an image without a chromatic component, but practically impossible to imagine the inverse. Lightness is measured in degrees of intensity and is bound at each end by zero and maximum.

- As lightness is an expression of a colour’s intensity, **hue** is the specific wavelength of that light. Hue is expressed as terms: words that define a particular range of the visible electromagnetic spectrum [22]. The hue range extends from purple (short wavelength) to red (long). The span of hue difference is navigated according to perceptually unique hues, which are red, green, blue and yellow. Hue has a strong semantic dimension. For example, a tree should not be blue and a sky should not be green.
2.2 Colour Spaces

Fig. 2.4  


(b) A normalised map of its saturation.  

(c) A normalised map of its lightness.  

Note the similarity of these maps

- **Saturation** defines the purity of the hue [13]. Similar to lightness, saturation is measured as degrees of intensity, bound at each end by zero and maximum. Zero saturation nullifies chromaticity, rendering it achromatic.

  The way that these values interact within a painting is noteworthy. In most paintings made before the modern era (which can be approximately defined as starting in the 1860s), the mapped saturation values look very similar to those of the lightness [7]. In Fig. 2.4 a painting by the French artist Jean-François Millet (1814–1875) is shown together with its lightness and saturation maps. Their similarity is clearly apparent.
In 1839, Michel-Eugène Chevreul (1786–1889) wrote ‘The Laws of Contrast of Colour’ [5]. Though it was intended for use by the design and printing industries, it had a significant impact upon the way that painters thought about colour. Taking the lead in this new thinking, Eugène Delacroix (1798–1863) was the first to knowingly and aggressively unlink saturation from lightness. Fig. 2.5 shows a painting by Delacroix together with its lightness and saturation maps. There is strong difference between their perceptual impact, the saturation map being very eventful, while the lightness map is evenly distributed. This difference is further discussed in Sect. 2.3.2 on p. 18.

Mapped as colour spaces, HSL and HSV form cylinders. The models of these two colour spaces are shown in Fig. 2.6.

In our work, hue is sourced by converting to HSL/HSV colour model. We also used HSL/HSV as our ‘thinking space’, for the discussion of the aesthetic values of an image.

Munsell, CIELab and LCH colour spaces. It excited eighteenth-century colour theorists, such as Johann Wolfgang Goethe, that according to Runge, colour could be expressed as a sphere. This was in agreement with their understanding of the universe
as being a layered and ordered thing, with God placed firmly in the centre (the so-called ‘harmony of the spheres’). It took another artist, Albert Henry Munsell (1858–1918), to prove how wrong this assumption was. In 1905, he developed the Munsell colour space [21]. It was painstakingly mapped as degrees of ‘barely noticeable difference’ using human perception as the point of reference. Munsell showed that far from being a regular form, when mapped as a volume, colour was extremely uneven (see Fig. 2.7). For example, there are more perceptually different degrees of ‘greenness’ than there are of ‘yellowness’.

In mapping the hues around the vertical axis of the space, Munsell arranged them such that any $n^\circ$ spread of hue values in one part of the wheel contains the same number of perceptually different hue values as those from another part of the wheel with the same degree of spread. Shown in Fig. 2.8 is the Munsell hue wheel (a) compared to an RGB hue wheel (b). Note how the green span within the Munsell hue wheel is larger than that within the RGB wheel. This corresponds to the human experience of green, which exists in more perceptually different shades than any other
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Fig. 2.8  a The Munsell colour. b The RGB colour wheel. Note the larger spread of the green span in the Munsell wheel

Fig. 2.9  The difference of the L channel in HSL and CIELAB spaces. a The hue ramp and L channel of HSL space. b The hue ramp and L channel of CIELAB space

hue. Munsell colour space was used in our work in the defining of global hue contrast (Chap. 10 of 179).

The CIELAB model is a direct descendant of Muncell colour space. It presents lightness in the $L$ channel and colour in the $a$ and $b$ channels. The $L$ channel of the hue ramp matches our perception of lightness (as shown in Fig. 2.9b). One of the features of CIELAB space is that saturation and hue are not located in either the $a$ or $b$ channels but are expressed as relationships between these two channels. In order to be expressed as hue, saturation and lightness, the CIELAB space is converted to LCH (lightness, chroma, hue) space by transforming the Cartesian $a$-$b$ coordinates of CIELAB to the polar $C$-$H$ coordinates of LCH. Chroma and saturation are related for expressing the colourfulness of a colour. In our study of depth-aware contrast, regional contrast and center-corner contrast, the LCH colour space is employed. The chroma in LCH space is indicative of saturation.

2.3 Colour Contrast

Simply put, contrast is a property of difference. In order for an object to be perceptually apparent, it is required to contrast its environment. This will likely be a contrast of lightness, but may also be a contrast of hue and/or saturation.
In visual art, the aesthetic organization of an image is managed through attention to its contrasts. These contrasts may involve any perceivable attribute of the image: theme, texture, size, etc. This is a fundamental principle of all art objects. For example, in an action movie, the drama is driven by the contrast of good and evil. It is the contrast of colour which this section addresses, and which is of prime importance in our work.

### 2.3.1 Itten’s Contrasts

In 1961, Johannes Itten (1888–1967) wrote ‘The Elements of Colour’ [16], in which he described seven colour contrasts. This book can be found in most art school libraries and has had a huge influence upon the way that colour is understood in the art domain.

1. **Contrast of Saturation**. This refers to the contrasting of regions of different saturation values.

2. **Contrast of Light and Dark**. This refers to the contrasting of regions of different lightness values.

3. **Contrast of Extension**. This refers to the way in which two or more regions, each of different colour, are effected by size. For example, a saturated region of the same size as an unsaturated region will perceptually overwhelm that region. Their relationship may be brought into balance by increasing the size of the unsaturated region.

4. **Contrast of Complements**. Complementary colours are pairs of colours that are located on opposite sides of the colour wheel. Examples of complementary RYB pairs are red/green, yellow/purple and blue/orange.

5. **Simultaneous Contrast**. First described by Chevreul, Simultaneous Contrast refers to a perceptual effect whereby one region of colour may change the apparent colour properties of another region. Hence, a mid grey against a dark grey will seem lighter than the same mid grey against a light grey.

6. **Contrast of Hue**. This refers to the amount of perceptually different hue values in an artwork. Simply put: an artwork with few perceptually different hue values has low Contrast of Hue, while one with many perceptually different hue values has high Contrast of Hue.

7. **Contrast of Warm and Cool** (aka colour temperature). This contrast assumes that some colours are perceived as warmer/cooler than others. Perversely, Itten describes two contradictory forms of temperature contrast: relative (such as the warm yellow of a sunflower versus the cold yellow of a lemon) and absolute. The latter divides the RYB hue wheel in half along the green/purple axis. Colours in the yellow to red-violet half are warm, colours in the other half are cool.

The first focus of our research served to examine how the contrast values of an artwork may be quantified. The second focus was to examine how these contrast values may be transferred to photographs (so-called style transfer).
Itten’s contrasts are used as a point of reference in much of our work. However, not all of his contrasts were applicable to our purposes. We assume that a style transfer will only effect the colour of pixels, not their placement. For this reason, the Contrast of Extension was not included in our study because it is primarily a contrast of size, not colour. We also did not consider Simultaneous Contrast to be, in the strict sense, a colour contrast. Rather it is a perceptual phenomenon (an optical illusion). Additionally, it is also not a major feature of art or photography, except in late modernism such as exemplified by the work of the Op Artists [8].

Though we use Itten as a point of reference, he is not without his failings. There are many errors and inconsistencies in his work. For example, he describes yellow as being ‘lighter’ than blue. This is clearly erroneous, as any hue has the potential to be lighter or darker than any other hue. However, he did an effective job at gathering known wisdoms of the time and remains a point of reference for engineers, seeking canon literature on the topic of pictorial aesthetics [9, 10, 24].

2.3.2 Structural Contrasts

Itten’s Elements of Colour is a collection of general observations describing the basic dimensions of colour contrast. They do not on their own address how the contrast of a painting is structured. This section addresses six structure-based contrasts: global contrast, center-corner contrast, local contrast, regional contrast, neighbouring regional contrast and depth-aware contrast. The notable thing about these contrasts is that they all serve distinctly different aesthetic functions within a painting.

1. Global contrast. Global contrast is a property of the entire image. A histogram is a visual expression of the global distribution of lightness or saturation within an image. Shown in Fig. 2.10 are two paintings, together with their lightness histograms. The chromaticity has been nullified in both paintings to make their lightness values easier to review. The first extends from black to white, with a predominance of darker values. The second extends from dark grey to light grey, with a predominance of lighter values.

The tonal range and distribution that Van Gogh employed is known by artists as high key and that employed by the unknown artist is known as low key [3]. Global contrast defines the primary impact of this range and distribution. This impact comes before any high-level consideration of content or structure, and may therefore be said to be a reflection of the painting as an object.

It can be simply observed that artists exaggerate upon nature. This is as true for painters in the handling of contrast as it is for writers and film-makers in the extreme fictions they craft. However, this exaggeration is not simply a linear increase (i.e. ‘the more the better’). The fugitive nature of skies, and their importance in establishing the emotional mood of a landscape, legitimatises any creative liberties that the artist wishes to take with them. This makes them suitable case studies when examining how artists exaggerate contrast. In Fig. 2.11 is shown the RMS contrast value of 30 skies (RMS contrast is described in Sect. 3.2 on p. 34). These are sourced from the work of the Hudson River school of painters. Clearly, many of the paintings are more
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Fig. 2.10  a ‘Portrait of a Young Lady’ (by an unknown artist, c1835) (left). b Van Gogh’s ‘Girl in White’ (1890). Courtesy National Gallery of Art, Washington. Inset their lightness histograms. Note the difference in their lightness distribution, which is a difference of global contrast.

Fig. 2.11  The RMS contrast value of 30 skies, sourced from the Hudson River school of painting, compared to that of skies sourced from 30 photographs. Distribution histograms are on the right. The difference in histograms evidences the artist exaggerating upon nature.
Fig. 2.12  a ‘A Polish Nobleman’, Rembrandt Van Rijn (1606–1669), 1637. Courtesy National Gallery of Art, Washington.  

c and d are their histograms. Note the general similarity of their histograms, yet the difference of their perceptual impact. This is the result of the difference in the spatial distribution of their values, with those of ‘Moroccan Horseman Crossing a Ford’ being even-form, and ‘A Polish Nobleman’ being event-form.

contrasty than the photographs. However, many of the paintings are also of very low contrast. Hence, the exaggeration employed by painters is one where similarity is as likely to be exaggerated as difference. In the words of the noted art theorist, Rudolph Arnheim: ‘...a configuration of colours will strive either toward contrast or toward assimilation’ [27].

The shortcoming of employing a histogram as a means of evaluating global contrast is that it lacks a spatial dimension. In Fig. 2.12 two paintings are presented: one by Rembrandt, the other by Delacroix. Despite the similarity of their histograms, these paintings are visually dissimilar in their perceptual impact. The lightness of the Delacroix painting varies evenly across the surface (even-form), while that of the Rembrandt painting is clumpy and focused around the event of the face (event-form). This exemplifies the spatial component of global contrast.

This difference between even-form and event-form global contrast is particularly important when comparing the global saturation of an image with its global lightness.
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It can be seen in Fig. 2.5 that the painter has enforced a strong difference between the spatial distribution of these two values. This even/event-form difference between the saturation and lightness distribution is a distinguishing feature of impressionist and post-impressionist painting and has had a huge impact upon our contemporary visual aesthetic.

In Chap. 3 on p. 33, computational models of colour contrast are discussed. However, there is currently no computational model we are aware of that satisfactorily differentiates between even-form and event-form global contrast.

2. Local contrast. Global contrast varies across contiguous regions of a painting, giving us local variations of global contrast, which we term local contrast. In a typical landscape painting, the lightness values of the foreground will range from black to white, while in the background they will range from dark grey to light grey. In the painting shown in Fig. 2.13 the lightness values of the foreground region extend from a near black to a near white, while those in the background region range from dark grey to light grey.

In a landscape painting, such differences in local contrast are used to enhance the impression of space. In a portrait painting, they are used to draw attention of the viewer to the face.

3. Centre-corner contrast. Centre-corner contrast is the contrast between the edges and corners of a painting and its approximate centre [3]. The centre and the corners of a painting are attributes of its picture plane, which is shown in Fig. 4.1. Centre-corner contrast can be found in both landscapes and portrait paintings and is an important component of the vignette effect, which is discussed in Chap. 4, on p. 39. The key function of the vignette and centre-corner contrast is to enhance the depth of the painting and to draw attention to the ‘region of interest’ (see Sect. 4.1.2 on p. 44).

4. Regional contrast. Regional contrast is the contrast between two colours and is therefore an entirely relative value (i.e. \(a\) may be lighter than \(b\) but darker than \(c\)). For an artist, relative judgements have substantial value in the process of painting during which an artist will evaluate the colours of specific regions not just for their fidelity to those of the subject, but also for their difference to other regions [2]. In other words, the artist seeks to be faithful to the relative organisation of the colours in a scene, not their absolute value. Local contrast relies upon pairwise comparison, which is the most efficient manner in which a human can make evaluative judgements [26]. Staggered sets of pairwise comparisons are employed by painters when they are establishing the colour values of their paintings. In the pictogram shown in Fig. 2.14, the piece of paper under the table is darker than that which is on top of the table, yet lighter than the floor under the table. This pairwise ordering emulates a simple sorting algorithm (a comparison sort), using which an artist sorts the colours within the painting into an agreeable configuration.

5. neighbouring regional contrast. As regional contrast is relative, it cannot be employed to evaluate the aesthetic value of a painting without first defining the terms by which the two compared regions are selected. It is therefore hard to address in a general manner. However, there is a subset of regional contrast that exclusively concerns neighbouring regions (see Fig. 2.15). This contrast serves to attract our eye
Fig. 2.13  a ‘Pastoral Landscape’, Asher Brown Durand, (1796–1886), 1861. Courtesy National Gallery of Art, Washington. b Regions within the FG and BG shown in comparison with histograms inset. The tones of the FG range from black to near-white, whereas those of the BG extend from light grey to dark grey. This is a difference of local contrast, and in landscape painting is used to enhance depth
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Fig. 2.14 In this pictogram, the piece of paper under the table is *darker* than that on *top* of the table, yet *lighter* than the floor. This is an example of the pairwise sorting algorithm that a painter makes in the process of painting.

(a)  
(b)

Fig. 2.15  
(a) Detail of ‘Profile Portrait of a Lady’, Franco-Flemish, c1410. This is an example of high neighbouring regional contrast of the face against the background  
(b) Detail of ‘Portrait of an Elderly Lady’, Mary Cassatt (1844–1926), c1887. This is an example of low neighbouring regional contrast of the face against the background. Courtesy National Gallery of Art, Washington

... to the centre of attention and is especially important in portrait painting, where it is employed to emphasise the head against the background.

6. **Depth-aware contrast.** In both landscape and portrait paintings, there is geometric organisation that supports the illusion of depth. Real-world depth exists as infinite degrees of difference between the viewer and the furthest object in the scene.
However, artists generally render depth as a few simplified planes. A portrait tends to employ no more than two depth planes: a FG and BG (i.e. figure/not-figure). A landscape may employ more depth planes, but usually no more than four (FG, MG, BG and sky, see Fig. 2.16). The depth-aware contrast of a painting is the contrast organisation that exists within the depth planes, and between the depth planes. These we term, respectively, ‘intra-contrast’ and ‘inter-contrast’ (see Fig. 2.17).

In landscape painting, the maintenance of the illusion of depth is of high importance, whereas in portrait painting, the expression of the figure and the face is prime. The figure in a portrait painting inhabits the middle vertical, while the background often serves only to provide a high contrast to the figure. Therefore, this book focuses on studying the depth-aware contrast organisation of landscapes and the regional and neighbouring local contrast organisation of portraits.
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2.3.3 Hue and Harmony

The preceding section described the various dimensions of contrast in a painting, which on their own do not describe an aesthetic evaluation of an image. Such is offered by colour harmony, which can be understood as describing good contrast. Since painting was first written about, there has been a declared assumption that some configurations of colour are better than others. However, defining exactly what constitutes this quality is a task that is still a work in progress, and one that is perhaps beyond reach.

Frequently cited on this topic is the notable work done by Matsuda. For a number of years he performed field studies on the fashion habits of female Japanese university students. He proposed a set of hue and tone templates (Figs. 2.18 and 2.19), the hue templates employing the RGB hue wheel. Any hue or tone/saturation configuration that conforms to the shaded regions of these templates is assumed to be harmonious.

Though these are frequently cited in reference to paintings and photographs [19, 24], their value outside of the domain of flat design is questionable. The ‘i type’ hue template would correspond to a painting of a single hue, something not found outside of late modernism. Similarly, ‘I type’, ‘T type’ and ‘X type’ configurations in painting are very rare. These templates are also very regular, while the hue histograms of paintings are typically very noisy and irregular.

Matsuda’s tone templates are similarly inappropriate for the aesthetic evaluation of painting. Almost all pre-modern painting features lightness (tone) that extends from black to white (an exception is shown in Fig. 2.10). This also is true of photography, and is the working assumption that is made by Photoshop’s ‘Auto Correct’ adjustment. Hence, only the ‘Value contrast’ and ‘Maximum contrast’ template would be applicable to paintings. We therefore observe that any consistent correspondence

Fig. 2.18 Matsuda’s hue templates. a i type. b V type. c L type. d I type. e T type. f Y type. g X type. h N type
between Matsuda’s templates and the colour organisation of paintings is probably wishful thinking.

Adobe’s advanced colour harmony picker ‘Color CC’ works in RYB colour space. Drawing from traditional literature on the topic, it references the following classic colour schemes:

- **Analogous**: colours chosen for their similarity of hue.
- **Monochromatic**: colours chosen for their identical hue (variance is supplied through differences of lightness).
- **Triadic**: three colours located at points evenly dispersed around the hue wheel.
- **Complementary**: colours chosen for their opposition on the RYB hue wheel.
- **Compound**: sometimes also called the split-complementary, this is a variant of the complementary wherein one of the complementary pairs is an analogous spread.

There is some correspondence between Adobe’s system and Matsuda’s. For example, Matsuda’s i type is a good match for the Monochromatic, and the V type for the Analogous. However, there are also significant dissimilarities. There is no match for the Triadic in Matsuda’s schemes, and Matsuda and Adobe reference different hue wheels. In this respect, we must remark that we find Matsuda’s use of the RGB wheel curious, as this colour wheel has no value in canon art literature, where the RYB wheel is the norm for evaluation of complementary pairs. The general impression that is given is that both Matsuda and Adobe are recalling the same poorly remembered event in a manner that is fuzzy and inconsistent. This we find to be symptomatic of artistic colour theory in general. Supporting this, Burchett [4] and Westland [28] both found that despite a plethora of enquiry into the topic, which extends over many centuries, there is no general agreement as to exactly what colour harmony is.
Even Goethe’s massive tome on so-called colour theory [27] is, by most informed accounts, nothing of the kind, being more the work of a poet than a fully-fledged theory [14].

These criticisms notwithstanding, Matsuda’s and Adobe’s systems reflect a general agreement that colour in art and design operates in a manner that is, in some mysterious way, subject to high-level ordering principles.

The subject of colour harmony is most often addressed in relation to the hue component of colour. Hue is very difficult to exactly quantify. The lightness and saturation of an image are understood through such values as least, most and average. However, the human experience of hue is defined as differences in terms (red, yellow and green). The word term was first used in this context by the perceptual psychologist Nault [22]. It was he who demonstrated that children, when reading maps, generally associate change in lightness and saturation with change in amount, such as depth and degree. However, change in hue they associate with a change in quality, such as the difference between water, land and coral. Consequent to this, no hue is inherently greater than another. Nor, in a hue event as complex as a painting, can there be such thing as an average hue, any more than there can be an average nationality in a room full of people. In other words, hue is dimensionally complex: not as easy to conceptualise as saturation or lightness.

Of pivotal importance in most colour harmony literature is the notion of complementary pairs [2, 16, 27]. In physics, a complementary pair is one that when mixed together produces a neutral (i.e. a grey). This mixing may be optical, such as Maxwell’s discs [20], or through admixtures of paint. For artists, a far more important property of a complementary pair is that they are as different to each other as can possibly be. This property has little empirical substance, maximum perceptual difference of hue being difficult to measure, but it nonetheless has a long history in the arts. In his book ‘The Art of Painting’, Leonardo Da Vinci (1854–1519) describes the colour pairs blue/orange and red/green as being opposite (retto contrario, literally ‘exactly opposite’) [11]: a clear reference to artist’s complementary colours. This predates any conceptualisation of the colour wheel.

Harmony in the visual arts is a notion that was originally borrowed from the world of music, which had long recognised that certain configurations of musical notes seem more agreeable to the ear than others. The first notable proponent of colour harmony was Johann Wolfgang von Goethe (1749–1832), a poet and philosopher who, in his ‘Theory of Colour’, saw himself as an antidote to Newton and his empiricism. Goethe placed the physiological experience of colour above its physical nature. The first time he mentions colour harmony is in reference to the complementary pairs:

...the eye especially demands completeness, and seeks to eke out the colourific circle in itself. The purple or violet colour suggested by yellow contains red and blue; orange, which responds to blue, is composed of yellow and red; green, uniting blue and yellow, demands red; and so through all gradations of the most complicated combinations. When in this completeness the elements of which it is composed are still appreciable by the eye, the result is justly called harmony.
Goethe is simply making the case that the aesthetic appeal of the complementary pair is one of ‘completeness’: that all three primaries are implied by a complementary pair (the secondary component of the pair being itself a mix of two primaries). This idea clearly excited him, and his book is full of assertions that any one hue cannot be experienced in isolation: that it naturally gravitates towards this completion which he terms harmony.

In his writing, Goethe constantly positions colour and colour harmony as something that reflects a larger universal order. Throughout the history of its usage, the word harmony is never far from such a spiritual reading. Pythagoras (c. 580–500 BC) described harmony as a mathematical order that found reflection in the order in which the planets crossed the heavens (the so-called harmony of the spheres). It is perhaps for this reason that Goethe’s work resonated greatly with early European modernists, many of whom were proponents of what we would now term ‘new age’ religions. The noted colourist, Wassily Kandinsky (1866–1944) was a Theosophist, and Itten himself was a proponent of Mazdaznanism, which was a fire cult. Goethe was a huge influence of Theosophy (H. Blavatsky) and Anthroposophy (R. Steiner), both of which are cultish in their outlook. They all wrote about colour in a manner that bordered on the religious. For example, in ‘Concerning the Spiritual in Art’ Kandinsky remarked that ‘orange is red brought nearer to humanity by yellow’ [17]. Goethe described the colour ‘yellow-red’ as being a favourite of ‘savage nations’ and ‘impetuous, robust and uneducated men’ and Itten himself describes the colours of a stained glass window as offering a ‘...direct invitation to higher spirituality’.

In summary, colour harmony has a lot of dubious baggage that is more suited to the religious domain than the creative or empirical. If colour harmony is a consistent and prescriptive system, then predictions could be made of it. For example: given the same problem (e.g. an incomplete painting), different artists would produce the same solution. We have seen no evidence that this is possible. Despite this, some general truths on the aesthetic application of hue in painting can be stated. These general rules of avoidance are detailed in Table 2.1. Importantly, these are more efficiently stated not as prescriptions (as in Matsuda and Adobe), but as avoidances. The difference between a prescription and an avoidance is interesting. Though ‘follow the path’ may seem to casual observation to be effectively the same as ‘keep off the grass’, in practice avoidance offers greater freedom of choice (e.g. ‘keep off the grass, but otherwise do as thou wilt’). It also allows for apparently contradictory directives to be observed.

Each of these three rules of avoidance we illustrate using examples from the Impressionist or Post-Impressionist era. These artists were famous for their rule-challenging experiments with hue and therefore present a limit-case test bed of these general truths. These rules are further substantiated by our work on hue contrast, as described in Chap. 10 on p. 179.
Table 2.1 Hue contrast in paintings: three general rules of avoidance

<table>
<thead>
<tr>
<th>Rule</th>
<th>Description</th>
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<tbody>
<tr>
<td>Avoidance of hue imbalance</td>
<td>Very few paintings employ hue values from only one half of the RYB hue wheel. Related to this is the rarity of monochrome paintings (i.e. paintings that employ only one predominate hue). Of 100 Post-Impressionist paintings reviewed, only six featured hue histograms that did not spread further than 180 degrees around the RYB hue wheel. An example is shown in Fig. 2.20, together with its hue values expressed within a RYB hue wheel. It can be seen that all its hues are variants of yellow.</td>
</tr>
<tr>
<td>Avoidance of hue balance</td>
<td>Very few paintings employ equal amount of hue values from one side of the RYB wheel as from the other. Of 100 Post-Impressionist paintings reviewed, only five obviously featured such balance. An example is shown in Fig. 2.21, together with its hue values expressed within a RYB hue wheel. This principle corresponds effectively to the original ‘rule of thirds’ as first stated by Sir Joshua Reynolds’s (1723–1792): ‘...in colours, whether of the warm or cold kind, there should be one of each which should be apparently principal and predominate over the rest’. (see Sect. 4.1.1 on p. 41)</td>
</tr>
<tr>
<td>Avoidance of hue ubiquity</td>
<td>Very few paintings employ every single hue. An exception is shown in Fig. 2.22, together with its hue values expressed within a RYB hue wheel. This can be evidenced by performing a Google image search on the term ‘garish colours’ (garish being a ‘taste’ word with pejorative connotations [15]). The results heavily feature ‘rainbow’ images which employ every single hue in the spectrum. Of 100 Post-Impressionist paintings reviewed, 15 displayed full hue ubiquity. Of these, seven were of the pointillist school, which was a group of painters that was defined by this very practice.</td>
</tr>
</tbody>
</table>

Fig. 2.20 a ‘Roses’, Van Gogh (1853–1890), 1890. Courtesy National Gallery of Art, Washington. b Its hue values expressed within a RYB hue wheel, showing hue imbalance: all hue values laying within one half of the hue wheel.
2 The Colour Attributes of Paintings

2.4 Concluding Remarks

This chapter described the many ways that colour in the art domain may be expressed. Clearly, it is a multidimensional phenomenon, with no single approach being applicable in all circumstances. We discuss colour spaces as different ways in which to model colour as a volume, each with their own particular application. We address Itten’s contrasts, which are a collection of general observations that describe the basic

Fig. 2.21 a ‘Fisherman’s House at Varengeville’, Edward Monet (1840–1926), 1882. Courtesy The Yorck Project, Wikimedia Commons. b Its hue values expressed within a RYB hue wheel showing hue balance: hues evenly distributed into two opposing masses of similar span.

Fig. 2.22 a ‘The Bay’, Paul Signac (1863–1935), 1906. Courtesy Szilas, Wikimedia Commons. b Its hue values expressed within a RYB hue wheel, showing hue ubiquity: hues in the spectrum having been employed.
dimensions of colour contrast. We present six structure-based contrasts: global contrast, centre-corner contrast, local contrast, regional contrast, neighbouring regional contrast and depth-aware contrast. Each of these serves a particular aesthetic function within a painting. We conclude with an examination of the history and practice of so-called colour harmony. Though we doubt that such a thing can be exactly codified, we nonetheless propose three general rules of artistic hue contrast. These are framed as avoidances rather than prescriptions.

This work serves as foundation for our research on transferring the style from paintings to photographs.

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Computational Approaches in the Transfer of Aesthetic Values from Paintings to Photographs
Beyond Red, Green and Blue
Zhang, X.; Constable, M.; Chan, K.L.; Yu, J.; Junyan, W.
2018, XV, 205 p. 148 illus., Hardcover
ISBN: 978-981-10-3559-3