CHAPTER 11

Colour mixing : Definitions and misconceptions

Introductory

At the outset of my life as an artist, my conception of colour-mixing was of a dry and mechanical subject. I thought of it as no more than one of those necessary basic skills that could easily be picked up along the road. To my surprise, nothing turned out to be quite so routine as it had seemed, and one line of enquiry led to another in a most seductive way. Each new development plunged me deeper into the history either of science or of art, until an engagingly coherent story emerged. The result was a practical understanding of a kind that might be difficult to find elsewhere.

Most how-to-do-it art books have sections on colour-mixing and there are a number of tomes that offer technical information for professionals. These latter tell us that scientists have understood the physics underpinning colour-mixing theory for a very long time: Certainly they have done so since James Clerk Maxwell's lecture on colour vision, given at the Royal Institute, two years before the First Impressionist Exhibition in 1874.

In view of the availability of all these sources of information, it might be thought that there is nothing left to add. Unfortunately, this is far from the case. Among the reasons are that:

- *Too many painters are being seriously misled by the half-truths and even falsehoods which have entered into the stock in trade of popular colour-mixing theory.*
- *Science has far from stood still since the 1870s. Scientists have found out a great deal about how the eye and brain work and, as a result, have arrived at a number of new understandings that could help artists in practical ways but which are not being made use of.*

For these reasons and others, it is clear to me that there is a need for the up-to-

date approach to practical colour mixing that is supplied by the next chapters.

One way of clarifying matters is to place the information presented in an historical context. Doing so reveals that:

- *Some of the best of ideas have been obscured by the passage of time.*
- *The story of when, how and why artists adopted new colour-mixing practices, provides many insights into their potential uses in painting.*
- *The evolution of colour-mixing theory, owes much to parallel development of the histories of science and of art. Unfortunately, the evidence for the links between the discoveries of the scientists of visual perception and the practice of the artists, is usually sparse and often ambiguous. Another problem is that history (not least the history of science) becomes distorted because it is told by people who write with the benefit of hindsight and sometimes from the perspective of a particular prejudice.*

It may surprise some people to find how many famous scientists are credited both with more originality and considerably more fully developed and rounded versions of their ideas than they actually had.[1] A mismatch of this kind also applies to the confusions relating to the early development of the ideas of Seurat and Cézanne and how they were to lead to the neat synthesis of them provided by Professor Bohusz-Szyszko.[2] Similarly it is unlikely that any of the early Impressionists had as clear a conceptual framework concerning the real surface/illusory space dynamic as was eventually to evolve from their pioneering ideas. While these are very interesting areas for research and discussion, the process of trying to unearth and pin down exactly what the early pioneers had in mind is a work for scholars. As the focus of this book is on practice, it is the ideas developed by more recent artists and theorists that will underpin what follows.

We start with some clarifications relating to words and phrases used in this book that are not always used in the same way by different authors (See also the "Glossary of Terms and Phrases").

DESCRIBING COLOUR

Colour space and the colour circle

Before diverging it is important to say something about the common ground

1 John Waller, 2006, *Fabulous Science*, OUP.

2 *Book 1, Chapter 1.*

found in all the books. All agree that the phrase "***Colour space***" is simply a way of thinking about all possible paint colours. It can be diagramatically represented as a sphere (*Figure 1*), whose three dimensions are *"hue"* (the range of pure colours),[3] "*saturation"* (from pure to neutral, taking in greys and browns) and *"lightness"* (black to white) [4]. It is a simplification of the situation as scientists conceive it, but their sophistications will add nothing that is of practical use to artists.

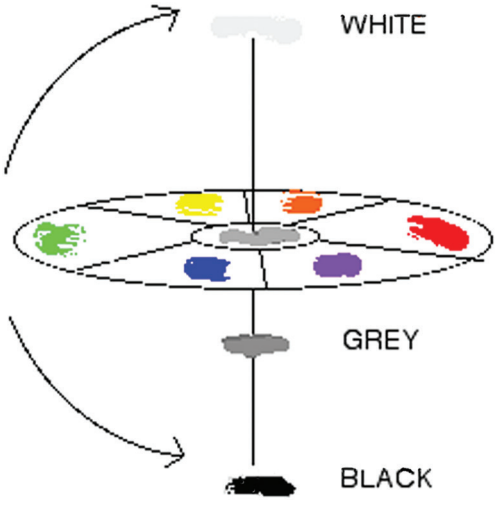

Figure 1 : Colour space represented as a sphere.[5]

The six segment disc in the middle of *Figure 1* represents what is left of the colour sphere if the "*lightness*" dimension is eliminated, leaving only the "*hue*" and "s*aturation*" dimensions. It is this that is known as the *"colour circle*". As we shall see later, both the colour sphere and the colour circle are splendid tools for artists when they want to think about any of the aspects of colour discussed in the colour mixing chapters of this book.

The three primaries

Many misconceptions arise because people assume that the entirety of col-

3 The colours of the spectrum produced by shining white light through a prism, colloquially known as words, "*all the colours of the rainbow*".

4 Scientists represent it more accurately as what they call a "*colour solid*", but the phrase "*colour sphere*" is simpler to think about and provides all the information necessary for artists.

5 In technical books it is described in other ways (for example as the "*Munsell Colour Solid*" or the "*CIE diagram*")

our-space can be created from mixtures of just three colours (described as "*the three primaries*"). However, this is not true, either for pigment-colour mixtures (subtractive) or for light mixtures (additive). The reality could hardly be more different. The fact is that the complete range of possible colours cannot be mixed from no-matter-how-many parent colours, let alone three of them, whether they are provided by pigments or by light sources.

Light primaries

To some people this last statement may seem provocative. However, it will be less so if they are reminded that, even though well-founded theory says that all prismatic colours can be created from combinations of the three light primaries, this is by no means the same as saying that all colours can be produced from simple mixtures between them. On the contrary, since all mixtures of light are lighter than the parent colours from which they are made, it is easy to see that mixtures of the light-primaries alone cannot produce at least half the colours in colour-space: No three light sources, however carefully chosen, can be blended to make greys, browns, ochres, earth-reds, etc.. To create these and, indeed, all the darker colours, the light-mixtures have to be placed in the context (both local and whole-field) of arrays of other, much lighter colours.[6]

But this is not all. It is also the case that no matter what combinations of the three light-primaries can be blended together to produce visual experiences that equate to those produced by any of the coloured surfaces we see (or could ever see) around us in the natural world. To create these, the mixtures would have to capable of mimicking not only the properties of body-colour but also of the light reflected from their surface,[7] and the necessary gradations would be quite impossible to achieve simply by blending any combination of the beams coming from any three light sources.[8]

Pigment primaries

The notion of there being three pigment-based primaries is also fraught with complication. Even if it were possible to obtain three "*ideal*" pigment-based col-

6 For some insights into this subject see Edwin Land's paper, *Experiments in color vision. Sci. Am. 200:84-94, 96-99*.

7 "Graininess" (density of specks of different pigments) and "*shininess*" (glossy to matt – absence, presence and density of shadows due to surface roughness).

8 The nearest matches would be "*transmitted colours*", ones seen through filters such as new leaves or stained glass. This is because, in this case, surface-reflection is in effective absent.

ours for this purpose, all mixtures between them would be darker than the parent colours. Accordingly, it would be impossible to mix lighter colours. In other words, it would be impossible to produce approximately one half of colour-space.

Another problem that is often glossed over is that no "*ideal*" triplet of pigment-based colours exists. All the candidates that could be cited have complex wavelength absorption profiles with the result that no pair of them could make either a truly desaturated colour or a truly pure grey. What this means in practice is that artists who use a palette consisting of no matter which choice of three pigment-colours, will severely restrict their potential for exploring ***colour-space***. In doing so, they will cut themselves off from the vast majority of obtainable colours. In short, it cannot be too strongly emphasised that it is a complete waste of time to search for three pigment-based colours that would fulfil the definition of the "*primaries*" as the three colours from which all other colours can be made.[9]

A different approach

In stark contrast to this negative state of affairs, we find that by turning attention away from the thankless task of finding non existent primaries and concentrating it on general principles, the five interrelated concepts of "***colour space***", "***colour-circle***" and "***complementaries***" have the potential of being of enormous practical value.

Later, in *Chapter 13*, we will be concentrating on a single problem, namely that of finding the range of greens needed for matching the vast array of colour-nuance to be found in the canopy of a tree. In addition to making possible the creation of the huge range of greens required, this conceptual approach will enable the discovery of analogous riches within colour ranges of any ***hue***, of any degree of ***saturation*** (greyness) or of any degree of ***lightness*** (tone/value). But, before we explain how a dose of historical and scientific background will give context to the ideas relating the ***colour-circle*** that come in later chapters.

Historical background

Colour-circles can be found in most books on the practice of painting. Frequently they are shown as in *Figure 1*. That is to say, as a slice through colour space, with ***six segments***, representing ***three primaries*** (red, blue and yellow) and their **complementaries** (green, orange and violet). This six segment arrangement

9 Although the search for the "*best*" three basic colours is of evident interest to printers using three colour printing processes.

was made popular by the ***Impressionists***, who, in the 1860s, were influenced by recent developments in *technology* and *science* that they saw as suggesting new possibilities for painting:

- The main contribution of *technology* was a huge extension of the range of new pigment-colours available. The artists were particularly delighted with their purity and brightness relative to previously existing pigment-colours. Indeed, they were so carried away with excitement that, erroneously but, significantly, they came to describe the most fully saturated of them as *"prismatic colours"*.[10] I use the word *"significantly"* because, talking as if any such thing were possible, gave credence to the false idea that all colours could be mixed from three primaries. It was only after Seurat that the need for much larger numbers of pigment colours became widely accepted
- As explained earlier, one of the key breakthroughs in *science* came from observations of *induced colour*, which led rapidly to a widespread acceptance of the idea that *colour is made by the head*. For artists, the writings of Goethe, the German, poet, playwright and scientist were particularly important in this process. On one occasion, he noticed violet shadows in a scene illuminated exclusively by a yellow candle flame and, on another, after staring fixedly at a beautiful woman in a red dress, was startled, when she went away, to see a vivid, green "*after-image"* on the blank, white wall situated behind where she had been seated.[11] In neither case could the colour in question have been created by light alone.
- Grist to the same mill was the discovery that all the multitude of colours in the spectrum can be matched using just three light sources and the consequent suggestion of Thomas Young that colour vision must be mediated by three visual channels (1802).[12] Later, came:
- Studies of interactions between neighbouring colours, famously published by Michel-Eugène Chevreul as the "*law of simultaneous-colour contrast*" (1839)[13]
- A new interest in optical blending, whether of mosaics of contrasting dots

10 Actually no pigment colour can have the quality of a prismatic colour.

11 J.W. Von Goethe, 1970, Theory of colours, M.I.T. Press

12 Thomas Young, 1802, On the Theory of Light and Colours, IN: Philosophical Transactions of the Royal Society of London, 92, pages 20-71

13 Chevreul, Michel-Eugene, 1839, De la loi du contraste simultané des couleurs et de l'assortiment des objets colorés, Paris

or alternating stripes (Mile and Chevreul, both 1939).

- The demonstration, by James Clerk Maxwell, the "*father of modern physics*", that a fast-rotating disc made of red and green segments appears as yellow rather than grey, thus behaving like mixtures of coloured light (1856).[14]
- The rescue from seeming oblivion of the ideas of Thomas Young by Hermann by Von Helmholtz, the "*father of psychophysics*", who gave them the central place in colour theory they still possess today (1867).[15]

Questions and some answers

From all this we discover that, when the young ***Impressionists*** were developing their conceptual frameworks in the 1860s, colour-theory was in a period of evolution. In their enthusiasm to create never-before-experienced effects of light and colour, Monet, Sisley and the rest seized on every scrap of new knowledge that arrived. However, since the scientists themselves were still in the process of assembling their own understanding, is it hardly surprising that the artists got a bit confused. Several puzzles concerning what they actually thought arise:

- What did the young *Impressionists* have in mind when they used the word "***prismatic***"? Could they have actually believed that the colours they described as such would mix like light?
- How, in the face of the reality of practical colour-mixing, could they have gone along with the idea that all actually possible colours can be created from three paint primaries?
- If only three primaries are necessary, why did they add the three, theoretically redundant, secondary colours to their palette, the ones they significantly chose to call "***complementaries***"?[16]
- Why, so soon afterwards, did Seurat and Signac opt for a palettes of eleven, twelve or more colours? And why did Cézanne, Bonnard and Matisse add significantly to that number?
- Why did Van Gogh choose yellow (rather than orange) as the complementary of blue?

14 James Clerk Maxwell, Theory of Perception of Colours. In: Transactions of the Royal Scottish Society of Arts, 4, pages 394-400

15 Helmholtz, Hermann Von, 1866, Physiological Optics.

16 Perhaps they baulked at leaving out the complementary pairs which, due to Chevreul, Goethe and others, played such an important part in their theorising.

Answers to some of these questions lie in the arrival of new information:

- (James Clerk Maxwell's demonstrations of differences between additive and subtractive colour mixtures (1872),
- The findings of Seurat's experiments designed to find a minimum of pigment colours that would mix to make the maximum number of the most fully saturated colours possible. With the artists pigments currently available, he found that the answer was twelve (twice the six that the earlier colour theory had proposed).[17]
- Ewald Hering's proposal of the now universally accepted yellow-blue opponent-colour cells in the brain (1877).[18]

In sum, the simplicity of the six segment colour-circle is deceptive for it hides a fascinating complexity of history, science and misconception. Luckily, today, the situation is clearer, allowing those who understand its fundamental shortcomings to make full use of its very real potential as a ***conceptual tool*** for exploring the wonders of the largest extent of ***colour-space*** available to artists.

Implications

There are enormous numbers of publications that have sections on colour-mixing. They cover the range from how-to-it books, written with beginners, to tomes providing highly detailed technical information at a professional level. These latter tell us that scientists at least have understood the physics underpinning colour-mixing theory for a very long time: Certainly they have done so since James Clerk Maxwell's lecture on colour vision, given at the Royal Institute, two years before the First Impressionist Exhibition in 1874.[19] This being the case, it might be thought that there is nothing left to add. Unfortunately, this is far from the case, for at least two good reasons:

- *Too many painters are being seriously misled by the half-truths which have entered into the stock in trade of popular colour-mixing theory. It is high time these were reassessed.*
- *Science has far from stood still since the 1870s. Scientists, including myself and colleagues, have arrived at a number of new understandings. I have*

17 In the 1970s, my artist friend Alan Cuthbert with the same goal as Seurat, but with an greatly extended range of pigment colours available, found that he required eighteen.

18 Which could perhaps explain why Van Gogh liked opposing yellow and blue in his paintings.

19 James Clerk Maxwell, 1872, *On Colour Vision*, Proceedings of the Royal Institution of Great Britain, 6, pages 260-271.

> *found no evidence that the authors of "how to do it" books on the practice of painting are acquainted with them. Nor have I come across paintings that convince me that the artists who produced them have incorporated them into their working practice.*

For these reasons and others, it is clear to me that there is a need for the up-to-date approach to practical colour mixing that is supplied by the next chapters.