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A DEFENCE OF THE STUDY OF VISUAL PERCEPTION IN ART

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ABSTRACT

This thesis examines the use of the science of visual perception in the study of art. I argue that this application of perceptual psychology and physiology has been neglected in recent years, but contend that it is being revived by writers such as John Onians. I apply recent scientific research to demonstrate what can be learned about depiction from the science of perception.

The thesis uses the science of perception to argue that there are four main interlinked components in depiction. It argues that each of these components can be better understood by using the science of vision.

Chapter 1 examines one component, namely resemblance. It uses studies of the retina, centre-surround cells, and attentional processes to examine how a picture can vary in appearance from its subject matter, yet still represent it.

Chapter 2 examines a second component, namely informativeness. It applies Biederman's psychological theory of recognition-by-components to argue that the depiction of volumetric forms depends on the depiction of the vertices of such objects, as well as that of linear perspective. From this the chapter argues that the notion of informativeness, as developed by Lopes, should be combined with a notion of resemblance to create a more complete theory.

Chapter 3 examines a third component of depiction, namely that pictures can include, omit, and distort the features of their subjects. The psychological theory of scales, as developed by Oliva and Schyns, is used to explain certain kinds of depictions of fabrics, and the perception of Pointillist paintings. The chapter also examines the issue of to what extent perception and depiction are dependent on culture rather than genetics, and shows how a combination of scientific methodology, in the form of cross-cultural psychology, and historiography, in the form of Baxandall's 'period eye' approach, can be used to investigate this issue.

Chapter 4 examines a fourth component of depiction, namely the organisation of pictures. It uses studies by Westphal-Fitch et al., and Võ and Wolfe to analyse the patterns of Waldalgesheim art, and the images in the Book of Kells.

By using the science of visual perception, I arrive at the conclusion that a combination of theories of recognition, informativeness, and order, developed in *Chapters 1*, *2*, and *4*, together with theories of visual decomposition, processing, and recomposition, developed in *Chapter 3*, form a basis for understanding depiction.

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Unless otherwise noted the model in all photographs is the author.

FIGURES

INTRODUCTION

ART AND PERCEPTION

> Art being a thing of the mind, it follows that any scientific study of art will be psychology. It may be other things as well, but psychology it will always be.

(Friedländer, 1946), quoted in (Gombrich, 1960, p. 3)

> Let there be, in a picture-gallery, a desert scene, in which a procession of Bedouins, shrouded in white, … marches under the burning sunshine; close to it a bluish moonlight scene, where the moon is reflected in darkness. You know from experience that both pictures, if they are well done, can produce with surprising vividness the representation of their objects; and yet, in both pictures, the brightest parts are produced with the same white-lead, which is but slightly altered by ad-mixtures; while the darkest parts are produced with the same black. …
>
> In order to understand to what conclusions this leads, I must first of all explain the law which Fechner discovered for the scale of sensitiveness of the eye, which is a particular case of the more general psycho-physical law of the relations of the various sensuous impressions to the irritations which produce them. This law may be expressed as follows: within very wide limits of brightness, differences in the strength of light are equally distinct or appear equal in sensation, if they form an equal fraction of the total quantity of light compared. Thus, for instance, differences in intensity of one hundredth of the total amount can be recognised without great trouble with very different strengths of light, without exhibiting material differences in the certainty and facility of the estimate, whether the brightest daylight or the light of a good candle be used.

(Helmholtz, 1881, pp. 95–96)

This thesis examines the theoretical background to the study of perception in art. The notion examined is the idea of 'art as a record of perception', the most influential version of which was developed by art historian Ernst Gombrich (1909–2001) in his 1960 book *Art and Illusion*. Gombrich explained his position:

> The art historian has done his work when he has described the changes that have taken place. He is concerned with the differences in style between one school of art and another, and he has refined his methods of description in order to group, organise, and identify the works of art which have survived from the past. … The art historian's trade rests on the conviction once formulated by Wölfflin, that 'not everything is possible in every period'. To explain this curious fact is not the art historian's duty, but whose business is it?

(Gombrich, 1960, pp. 3–4)

Gombrich turned to psychology to solve the riddle of style. His proposed solution was the 'illusion' theory, summarised by art historian and philosopher Dominic Lopes:

> According to Gombrich's survey of the history of art, depiction advances by abandoning its substitutive origins. Early art is the product of a desire to create substitutes for things, and is consequently free from the demands of mimesis. In later art, pictures become records of visual experience rather than substitutes, their purpose being to create an illusionistic match with viewers' experiences of their subjects.

(Lopes, 2004, p. 78)

Gombrich's proposal is only one theory of art as perception. In this thesis we will examine such ideas, and other evidence, to develop a theory that can form a basis for the study of perception in art.

The examination of perception in art goes back a long way. As can be seen in the quote above by scientist Hermann von Helmholtz (1821–1894), it was very popular in the Victorian era. Helmholtz notes that the visual system detects light in a roughly logarithmic scale, which allows artists to paint both bright sunlight and the moon with the same paint, even though the sun is 80,000 million times brighter than the full moon. This is illustrated by the below diagram, which shows how the increase in perceived intensity levels off, even as the actual intensity gets higher and higher (Figure 1, p.20.)

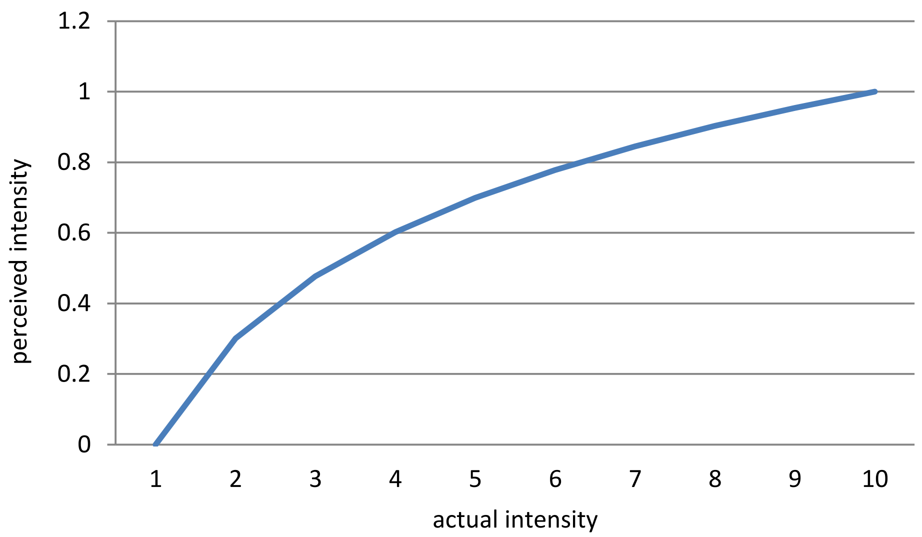

Figure 1 Graph illustrating the relationship between the perceived and the actual intensity of light. Diagram by the author.

As we can see in the diagram, successively greater levels of light of the subject can be depicted by smaller and smaller increases in the level of brightness of the picture. This is just one of the many insights the psychological approach can provide for the understanding of art.

Perception has been studied by art historians, psychologists and physiologists, and also artists. To begin this thesis we will look at the history of examining visual perception via art, followed by a summary of the current knowledge of the workings of the visual system.

ART AND PERCEPTION IN HISTORY

The study of vision dates back to the ancient Greeks. Euclid's c.300 BCE book *The Optics* presents an attempt to understand perspective, asking why parallel lines appear to converge in the distance, and why objects in the distance appear smaller than those closer to us (Euclid, c.300 BCE). Onians points out that in the ancient Greeks we can also see the beginnings of theorising on biological aesthetics. He quotes Aristotle:

> The poetic art seems to have been born entirely from two causes, both of them natural [phusikai]. First, imitation is an instinct in men from childhood and in this they differ from other creatures, being the most imitative and learning the first lessons by imitation, and everybody enjoying imitation.

(Aristotle, c.335 BCE, p. 1448b), quoted in (Onians, 2008, p. 25)

Despite the enthusiasm of the ancient Greeks, the discovery of the mechanisms of vision was a tortuous affair. Much of the knowledge of vision that we now consider common sense is in fact far from obvious, and was only discovered after a long process of physical and physiological experiment, and philosophical examination. The extent of the difficulties of elucidating the nature of light and vision can be seen in the strangeness of early optical theories. For example, the fifth century BCE Greek writer Empedocles believed that white light was detected by what he described as fiery pores in the eye, and that black objects were detected by watery pores. The later Democritus believed that the eye sends 'eidola' ('images') into the air, and that these eidola then proceed to take imprints of objects in a way similar to wax seals, which are then returned to the eye. Furthermore, it was not even clear to writers and theorists that there is a distinction between light and vision, demonstrating how difficult the process of discovery of the properties of vision has been. We will see in this thesis that even in the twentieth century there have been intense debates about vision that even now are not resolved, and that the discovery of the workings of the visual system's processing still does not proceed in a linear manner (Finger, 1994, p. 67).

> The duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads, and … attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency.
>
> (Ibn al-Haytham, 1011–1021)

The baton of progress was taken from the Greeks and Romans by the Islamic world. Arab scientist Ibn al-Haytham (c.965–c.1040) wrote a number of treatises on light and vision, including *Kitab al-Manazir (The Optics)*, which built on the work of the Greeks. Notable in Ibn al-Haytham's approach was his emphasis on the need for experimentation (Ibn al-Haytham, 1011–1021).

Medieval European investigators continued the study of optics, but it was in the Renaissance that major new developments began to take shape. Notably for us here, writers on optics were joined by artists such as Filippo Brunelleschi (1377–1446) in developing the laws of perspective (Edgerton, 2009, p. 74).

People today tend to view art and science as separate activities. In the Renaissance, however, there was no clear distinction. Anatomist Andreas Vesalius (1514–1564) and astronomer Galileo Galilei (1564–1642) had to be consummate draughtsmen in order to produce drawings of muscles and planets; artists such as Brunelleschi engaged in problems of the forces involved in architecture. Edgerton notably observes that it was in the Renaissance, with Brunelleschi and Leon Battista Alberti (1404–1472), that vision science became of real importance to art (Edgerton, 2009, p. 9).

The main interest of artists in relation to optics of the Renaissance was again perspective. Alberti wrote extensively about this topic in his treatise *De Pictura* (On Painting) (Alberti, 1435). Alberti would also attempt scientific explanations for optic phenomena:

> We know for a fact about these median rays [the less central rays] that over a long distance they weaken and lose their sharpness. The reason why this occurs has been discovered: as they pass through the air, these and all the other visual rays are laden and imbued with lights and colors; but the air too is endowed with a certain density, and in consequence the rays get tired and lose a good part of their burden as they penetrate the atmosphere. So it is rightly said, that the greater the distance, the more obscure and dark the surface appears.

(Alberti, 1435, pp. 42–43), quoted in (Edgerton, 1975, p. 84)

The interest in vision science by artists continued to grow, and expanded to other areas. For example, Onians notes the interest William Hogarth (1697–1764) had in the way that acuity of vision is lower away from the visual focus:

> Now as we read, a ray may be supposed to be drawn from the centre of the eye to that letter it looks at first, and to move successively with it

> from letter to letter, the whole length of the line: but if the eye stops at a particular letter, A, to observe it more than the rest, these other letters will grow more and more imperfect to the sight: the farther they are situated on either side of A, as is express'd in the figure.

(Hogarth, 1753, 1997, p. 33), quoted in (Onians, 2008, p. 59)

Notably, philosopher John Locke (1632–1704) wrote about the processes of visual perception in materialist terms. Though his writing was largely speculative, due to the slim experimental knowledge of the time, his writing of mental processes in physical terms would lay the intellectual groundwork for the future exploration of vision in experimental terms:

> The pictures drawn in our minds are laid in fading colours; and if not sometimes refreshed, vanish and disappear. How much the constitution of our bodies are concerned in this; and whether the temper of the brain makes this difference, that in some it retains the characters drawn on it like marble, in others like freestone, and in others little better than sand, I shall here inquire; though it may seem probable that the constitution of the body does sometimes influence the memory, since we oftentimes find a disease quite strip the mind of all its ideas, and the flames of a fever in a few days calcine all those images to dust and confusion, which seemed to be as lasting as if graved in marble.

(Locke, 1690) Book 2, Chapter 10, Section 5

It was the nineteenth century that saw an explosion in the study of vision science, and it was at this time that major progress was made in the various combinations of art and vision science. Physicist James Clerk Maxwell (1831-1879) wrote about colour vision, and influenced the Post-Impressionist Georges-Pierre Seurat (1859–1891). Experimental psychologist Gustav Theodor Fechner (1801-1887) influenced the

Symbolists, and via philosopher Ernst Mach (1838–1916), Soviet Socialist Realism. Another contribution was by physicist Ogden Rood (1931-1902), who lectured on optics at the National Academy of Design in New York (Agursky, 1997, p. 249) (Rewald, 1956, p. 83).

Helmholtz was one of the most prolific writers on the application of science to art in the nineteenth century. The chapter 'On the Relation of Optics to Painting' of his 1881 book *Popular Lectures on Scientific Subjects* is one of the most comprehensive nineteenth century applications of science to the study of art. The chapter is divided into four sections: Form, Shade, Colour, and Harmony of Colour. Helmholtz used a number of different scientific experiments to explain art, including Fechner's Law, as we saw above (Helmholtz, 1881). We will see in this thesis how some of Helmholtz's ideas were challenged by another scientist, the German Ewald Hering (1834–1918).

Another important example of nineteenth century artists being interested in vision science concerns the work of French scientist Michel Eugène Chevreul (1786–1889). The examination of Chevreul's work by Eugène Delacroix (1798–1863) set up a dynamic between artists and scientists that would include the work of artists Seurat and Paul Signac (1863–1935), and colour scientist Albert Henry Munsell (1858–1918) (Düchting, 1999) (Munsell, 1905) (Cochrane, 2014).

Chevreul was a chemist who worked at the Gobelins tapestry factory in Paris. The factory was having problems making their tapestries bright and colourful, so they asked Chevreul to examine the chemical composition of the dyes they used. Chevreul, however, realised that the optical properties of the arrangement of colours are as important as the chemical properties of the dyes. As a result he developed three colour theories, which he published in the 1839 *The Laws of Contrast of Colour*. Chevreul's theories were *successive contrast, simultaneous contrast,* and *optical mixing.*

Chevreul noticed that the contrasting properties of light of two objects or situations often result in the enhancement of the objects' or situations' properties. He wrote:

> (8.) IF we look simultaneously upon two stripes of different tones of the same colour, or upon two stripes of the same tone of different colours placed side by side, if the stripes are not too wide, the eye perceives certain modifications which in the first place influence the intensity of colour, and in the second, the optical composition of the two juxtaposed colours respectively.

(Chevreul, 1855, p. 7)

We will look at Chevreul's ideas in more detail later in the thesis.

The nineteenth and early twentieth century in Germany and its close neighbours saw a flowering of 'critical historians' of art. The period produced many major art historians such as Alois Riegl (1858–1905) and Heinrich Wölfflin (1864–1945), who notably for us here examined art history in terms of psychology. Podro notes that Riegl and Wölfflin attempted to find general principles of interpretation in terms of psychology. Riegl developed the idea that humans have innate senses of pattern that are expressed through ornament; Wölfflin developed ideas such as an empathy theory of architecture, whereby we instinctively note the similarity between our bodies and buildings, and a cyclical theory of artistic development, whereby artists begin by delineating forms, move onto a more optical approach, then repeat the process (Podro, 1982, pp. 95, 99, 103, 117).

The writings of the 'critical historians' are of incredible critical and descriptive power: Podro writes of Wölfflin that 'for many of us, whatever our reservations, it would be hard to find a replacement for the *Principles of Art History* [Wölfflin's 1915 book] as a model for the analysis of painting' (Podro, 1982, p. 98). Podro also, however, notes that one of the later critical historians, Erwin Panofsky (1892–1968), argued that whatever the richness of Wölfflin's descriptions in *Principles of Art History*, Wölfflin did not actually demonstrate their critical relevance to history. Panofsky observed that studies of social life demonstrated the importance of society in art, which called into question the idea that there are innate properties of the mind. How, it was asked, did we know that mental properties are not the product of society, rather than being innate? (Podro, 1982, pp. 178–179).

Panofsky developed an account largely based on the ideas of Georg Wilhelm Friedrich Hegel (1770–1831), but in this thesis we will examine an alternative account, based on the biological basis of neuroscience. We will see that this not only provides explanations for many artistic phenomena, but the understanding of the biological properties of the mind provides the possibility of finding a solution to the problem of differentiating between innate mental properties and their social and environmental expression.

Vision science continued to be researched into the twentieth century, thus providing us with many of the tools that will facilitate our quest. The main questions that have been examined in visual psychology are visual perception, the art of young children and the personality of artists. One of the most important researchers was psychologist and physiologist Daniel E. Berlyne (1924–1976). Berlyne's work differed from Helmholtz's in that Helmholtz restricted himself to visual perception. Berlyne not only applied experimental data to art but actually attempted to quantify and measure the effect of aesthetic experience on the whole nervous system, including the faculties of emotion and desire. He is said to have been of pivotal importance to modern psychological aesthetics. He used experiments to discover what stimuli arouse an organism and motivates the organism's behaviour, and also examined the methodological problems that separate experimental science and art history.

Berlyne's major work was his 1960 *Conflict, Arousal, and Curiosity*. In this book he examined 'motivation of perceptual and intellectual activities'. He argued that organisms are aroused by sensory stimulation, that different stimulations cause an organism to have conflicting motivations, and that organisms actively seek out stimulation. He argued that organisms have a desire to seek out novel stimulations, and the arousal that uncertainty brings, but also have the desire for relief from uncertainty; hence that organisms have conflicting desires for arousal and relief (Berlyne, 1960).

Berlyne would subsequently develop his analyses into a quantifiable relationship between arousal and complexity. It was with this that he would create his most important proposal. He argued that there is an inverted-U-shaped relationship between arousal and increasing complexity. As complexity increases, Berlyne argued, interest increases, until the complexity becomes too much, and the organism begins to lose interest.

Berlyne based his arguments on a range of scientific sources, including experiments on animals, observations of children and adults, neurophysiology, and information theory. The specific theory of the inverted-U-shaped relationship between arousal and complexity has, however, received conflicting support in subsequent experiments, though the methodological areas of Berlyne's work continues to be influential (Matchotka, 1980) (Messinger, 1998).

The twentieth century did, however, see something of a decline in the interest in art of vision science. This might be a consequence of the division of the intellectual world into 'art' and 'science', together with the resulting lack of knowledge by scientists about art and those working in the humanities about science. We can see this in a 1959 quote by scientist and novelist C. P. Snow (1905–1980) about something another scientist said to him in the 1930s:

> Have you noticed how the word 'intellectual' is used nowadays? There seems to be a new definition which certainly doesn't include Rutherford or Eddington or Dirac or Adrian …
>
> (Snow, 1959, p. 4)

Though muted, vision science remained of interest to both artists and art historians as the twentieth century continued. In art, painters such as Victor Vasarely (1906–1997) and Bridget Riley (born 1931) explored optical principles in the 'Op Art' movement, which became notable in the 1960s (Riley, 2009, p. 332). In art history, the 1960s and 1970s brought what are perhaps the seminal examples of the application of vision science to art, namely Gombrich's two books: the 1960 *Art and Illusion: A Study in the Psychology of Pictorial Representation* that we touched on earlier, and the 1979 *The Sense of Order: A Study in the Psychology of Decorative Art.* These works deal with the psychology of figurative art and the psychology of decorative art respectively.

Art and Illusion, as we noted earlier, is an attempt to answer one of the most basic questions in art history: 'Why is it that different ages and different nations have represented the visible world in such different ways?' (Gombrich, 1960, p. 3). Gombrich argued that art history's task was only to describe historical change, and hence the reasons for these changes must be found outside of art history. The source of explanation Gombrich proposed was psychology.

Gombrich argued for the importance of psychology, but resisted psychological reductionism. He argued that the application of psychology to answer the riddle of figurative style might only provide some of the answers, arguing that the study of taste, for example, might not be amenable to study by psychology. It is interesting to observe, however, that Gombrich dedicated the first chapter of his later *Sense of Order* to 'Issues of Taste', perhaps indicating that his belief in what could be learned from psychology increased over time.

Gombrich argued for what has become known as an *experiential* theory of depiction. Newall identifies experiential theories as one of four main contemporary theories of depiction, the others being *resemblance* (the deceptively simple theory that a picture looks like, or more precisely shares visual properties with, what it depicts), *conventionalism* (the theory that a picture is made up of symbols that the viewer decodes), and *recognition* or *visual response* (the theory that a picture utilises the same features of the mind that are used to recognise the real world, or that a picture causes the same visual response as would the depicted object itself) (Newall, 2011). Gombrich's theory in *Art and Illusion* is of the category Newall describes as experiential, namely that pictures 'occasion' a particular experience in the viewer. In Gombrich's theory, the experience that is occasioned in the viewer is that of an illusion.

Gombrich's theory was very influential, so it will be of value to examine it in further depth here. Gombrich quoted the legendary contest between ancient Greek artists Parrhasius and Zeuxis, who both claimed to be able to create the most illusionistic painting. Zeuxis thought he had won when a bird came down to eat the grapes in his still life, only to be humiliated when he attempted to pull back the curtain on Parrhasius's painting to find that the curtain itself was the painting. What was of interest to Gombrich in this tale was the idea of what he terms the ability of the human mind to 'close the gap', namely to be deceived that the image is indeed reality. We might argue that this is an aim unlikely to be achieved; even the great Parrhasios only achieved this illusion for a fleeting moment. Indeed, the only way that such an illusion could be achieved to any reasonable standard would involve vast computing power and virtual reality implants in the brain. Gombrich, however, would argue that this is not quite the point: one does not have to be consciously deceived at all to appreciate art, it is as if only part of the mind needs to be deceived. He gives the amusing example of Charlie Chaplin to illustrate this: Chaplin 'performs a dance with a pair of forks and a couple of rolls that turn into nimble legs in front of our eyes'. At no stage are we consciously deceived by Chaplin; we are fully aware that the bread rolls do not actually transmute into a pair of dancing legs. However, somewhere in our mental apparatus we have the illusion of a pair of dancing legs. Gombrich thus argued that we can alternate between a number of different interpretations of an image: we appreciate a Dutch landscape painting as a landscape alternating with a flat piece of cloth covered with mineral particles and hardened oil, and a figure by Michelangelo as a naked male alternating with a large piece of chiselled marble. This theory of illusion was used by Gombrich to explain how figurative styles develop and why there are, and have been, so many of these styles across the world. This is of interest to us here because Gombrich created a theory that not only describes how figurative styles arise, but links art history and psychology together (Gombrich, 1960, p. 172).

Gombrich not only argued for a theory of the experience of paintings, but argued for a theory of how painting developed. An example of this is his examination of the work of John Constable (1776–1837). Constable might be thought of as an artist who worked directly from nature, and is thus not of much interest in terms of style or history. Gombrich argued that such a view of Constable is wrong. Gombrich suggested that Constable thought of his paintings as experiments, intended as an 'inquiry into the laws of nature'. In order to achieve such an aim, Gombrich pointed out that it is naïve to think that Constable would simply sit in front of a field or a river and allow his painting to be guided by the sights he saw. Gombrich argued that Constable would be guided in his observations of nature by pre-existing ideas, which could be termed 'traditional schemata', as well as by ideas being developed in the world around him. Gombrich noted, for example, that Constable performed a series of copies of drawings by a landscape painter from the generation before him, Alexander Cozens (1717–1786), and that through this Cozens' work influenced Constable. This seems to be in opposition to the aims of Constable's art: if an artist wishes to investigate nature, he or she might do best to paint directly from nature, and use nature as his or her only guide. Gombrich, however, argues that it is impossible to proceed like this; an artist must begin with the discoveries of others, utilise these in his or her own discoveries, and later pass these new discoveries onto others who then repeat the process (Gombrich, 1960, pp. 150–152).

Two consequences of this theory are firstly that Gombrich argued for the importance of history and historical precedent in the work of artists, and secondly that the individual also has a role in art. Gombrich thus not only proposed that culture and the individual are of importance, but also delineated a mechanism by which they interact. Gombrich furthermore noted that not only was Constable influenced by the work of other artists, but that his depiction of clouds seems to echo the work of contemporary meteorologists' taxonomy that divides cloud forms into cumulus, cirrus and stratus. Gombrich thus argued for the importance of the general society in which an artist works.

Gombrich thus proposed for a 'filing system' in the mind, which organises data. In this he was influenced by the 'searchlight' theory of perception, which was developed by philosopher of mind Karl Popper (1902–1994). This filing system begins with the filing system inherited from previous artists and other cultural precedents, but is built upon by the new artists by the use of his or her own discoveries, and filing systems taken from the surrounding culture such as the meteorological taxonomy in the example above. Gombrich thus argued that figurative style is a process whereby the mind organises its repertory of figurative elements in an interactive and ongoing fashion; taking from precedent, and modifying it with the use of wider culture and the artist's own discoveries. Each culture will have its own distinct precedents and individual artists, and thus will develop a distinct style (Gombrich, 1960, p. 271) (Popper, 1945).

The Sense of Order is Gombrich's second major book on psychology and art. *Art and Illusion* deals with depiction, while *The Sense of Order* deals with abstract and decorative art. This thesis deals primarily with depiction, so *The Sense of Order* is of less importance here, and thus we will examine it in less depth. *The Sense of Order* is based around a notion first developed in *Art and Illusion*, namely Popper's searchlight theory of perception. Popper argued that there are two ways of viewing the mind: the 'bucket' theory, and the 'searchlight' theory that we met above. The bucket theory assumes that perception is a passive process; we simply sit there waiting for information to come into our minds. The searchlight theory, which both Popper and Gombrich favoured, assumes that the mind actively seeks out information. We might note that this theory has similar features to Berlyne's theory of the inverted-U-shaped relationship between desire and complexity, in which an organism actively seeks out stimulation. What Gombrich adds to theories such as those of Berlyne is a developed theory of perception. Berlyne's theory focuses on desire, and the organism's search for that which it finds attractive, and while Gombrich does not contradict such theories, he instead examines the more precise question of what it is that we desire. Gombrich suggests that we have a 'theory', or 'sense', of order in our minds. We seek out order, such as the repetitions of human-made objects like paving slabs, as well as disorder, such as crazy paving. When we are used to order, we seek disorder, and when we are used to disorder, we seek order. Hence we go through our environment constantly scanning, and pick out things that do not fit our current understanding of the world. When we see something, Gombrich gives the example of a perfect circle of mushrooms in the random vegetation of a wood, it grabs our attention because it goes against our expectations. This process is ongoing; when accustomed to irregularity in a situation, we become bored and immediately focus in on regular features; but also, we quickly become bored with regularity in pattern and our minds search out irregularity. Gombrich noted also how this process is limited: we have the desire for rhythm, due to the constant search for irregularity being tiring. As a result children enjoy repetitious games, and also learn the necessary skill of observing repeated patterns; necessary, for we need to detect the patterns as much as we need to detect irregularities (Gombrich, 1979).

Despite there having been something of a decline in general in the interest in vision science in the arts, its application to art continues into the present day. Notably it is able to benefit from the large amount of recent scientific research into visual perception, much of which features in this thesis. For example, neuroscientist Margaret Livingstone has continued the work of Weber and Fechner in investigating further the relationship between intensity and perception (Livingstone M. , 2002) (Livingstone, Pettine, Srihasam, Moore, Morocz, & Lee, 2014).

The behavioural approach has been superseded by more cognitive-oriented and neurobiological research. Kim and Blake, for example, have used Magnetic Resonance Imaging (MRI) to examine how brain activity patterns change when viewing abstract paintings with implied motion (Kim & Blake, 2007).

It is notable how this scientific and cognitive approach has been mirrored by historical research. The work of art historian Michael Baxandall (1933–2008), which we will meet in this thesis, is a notable example of this. In his method of the ‘period eye’ Baxandall examined the visual skills of peoples in different periods, and showed how they affected the creation of art of these periods. For example, he proposed that the introduction of teaching three-dimensional geometry in German schools affected artistic production. He argued that German boys started to be educated in three-dimensional geometry to allow them to calculate volumes of barrels and containers for pricing, and this developed in those boys a sensitivity to the perception of volumetric form. This sensitivity in turn, Baxandall argued, resulted in artists producing artworks with increasing levels of volumetric form, such as more solid-looking sculpture (Baxandall, 1980).

One of the problems with Baxandall’s approach, however, is that it does not in itself propose an actual theory and mechanism by which the mind actually develops this ‘cognitive style’, as Baxandall’s approach is sometimes called. Baxandall wrote:

> The light enters the eye through the pupil, is gathered by the lens, and thrown on the screen at the back of the eye, the retina. …
>
> It is at this point that human equipment for visual perception ceases to be uniform, from one man to the next …

(Baxandall, 1972, p. 29)

Baxandall did not actually propose a mechanism which explains what goes on in the rest of the human equipment for visual perception. However, art historian John Onians has joined together the sort of approach Baxandall used with the idea from contemporary neuroscience of ‘neuroplasticity’, namely the idea that the brain develops over the course of one’s life as a result of one’s experiences and learning. Onians notes that

> the connections between our neurons tend either to multiply or die back, and to become better or less well insulated, depending on how frequently and intensively they are used. We cannot yet monitor this process in detail, but the principles by which it is regulated are clear.
>
> (Onians, 2016, p. 9)

Hence the processes by which we learn about the visual world, for example the study of volumetric form by Renaissance German boys, will encourage particular connections to form between neurons, while discouraging others.

The '70s and '80s saw other ideas appearing in art history. One of the chief promulgators of what would become known as the 'new art history' is Norman Bryson, whose 1983 *Vision and Painting: The Logic of the Gaze* is one of the major books on the topic.

Bryson argued that Gombrich's 'perceptualism', as Bryson called it, has a flaw. He noted as an example the way that depictions of the nativity acquired fixed characteristics, for example the Virgin's irregular oval mattress and the way she always reclines to the right, that cannot be explained by the idea that art proceeds towards a more accurate depiction of reality as we perceive it. The Virgin could be placed on any number of beddings in any number of positions, and understanding perception as it relates to realism will not necessarily take us any further in understanding these changes (Bryson, 1983, p. 45).

Panofsky and the tradition of iconography might be the obvious contender for the study of such changes, for example Panofsky's discussion of the placement of the figures in Raphael's 1500 *The Choice of Hercules (?)* (London: National Gallery) (Podro, 1982, p. 193). Bryson, however, argues that 'iconology on its own tends to disregard the materiality of painting practice; only in a "combined analysis" giving equal consideration to "signifier" and "signified" within the painterly sign can this structural and self-paralysing weakness be overcome' (Bryson, 1983, p. 38). This seems unfair if we consider, for example, Panofsky's attempts to show the role public disputation might have had in the physical integration of the structural elements of Rheims cathedral (Podro, 1982, p. 202), but let us ignore this unfairness here, and instead concentrate on Bryson's ideas of 'materiality'. The question we must ask is whether semiotics provides for this 'materiality', and gives 'equal consideration' to the signified that Bryson finds lacking in iconology.

In order to answer this question, we might briefly examine some of the ideas of semiotics that have been influential in art history. One of the most important writers on semiotics was Charles Sanders Peirce (1839–1914). Peirce wanted to put linguistics on a firmer intellectual basis. He noted that words and signs had varying qualities: some might be totally abstract, having no relationship to the objects they denote, while others (like Chinese letters) might share qualities with the things they describe.

Peirce created a system of three categories with which to classify signs. Firstly there is the *icon*, a sign that to varying extents shares properties with the object being symbolised, for example the Chinese character for mountain; secondly there is the *symbol*, a sign that is arbitrary, for example the English word for mountain; and thirdly there is the *index*, a sign that points to or refers to the object being denoted, such as an index finger pointing at a mountain (Peirce, 1991).

This classification system has proved fruitful both in linguistics, and the study of art and culture in general. For example, cultural theorists often point out that celluloid film is more embedded in the physical world than digital film. The increase in digital media on the internet has resulted in images becoming increasingly divorced from their source, in an extreme version of the way Marilyn Monroe disappears in Andy Warhol's *Marilyn Diptych* (1962). Cinema theorist Laura Mulvey (born 1941) uses Peirce's classification system as a useful way of expressing this concept, namely as celluloid-as-index and digital-as-symbol (Mulvey, 2009, p. 190).

Another influential writer on semiotics relevant to the current discussion is Ferdinand de Saussure (1857–1913). Saussure lived in a time when linguists were preoccupied with studying the sources of words; for example, investigating why certain words in English sound similar to Indian words, while being very different to Chinese words. Saussure argued that such projects are somewhat irrelevant to people who use a language. He proposed that the nature of words is essentially arbitrary. It does not matter, he argued, to the English that they say 'night', while the French say 'nuit'. We can note that this idea that symbols are essentially arbitrary is somewhat in conflict with Peirce's idea of the icon, index and symbol. In Peirce's scheme two of the three types of sign are not arbitrary, but in Saussure's view all signs are arbitrary. Saussure believed that what was important in language is *structure*, which led to the movement that became known as *structuralism* (De Saussure, 1916, 2011).

Saussure argued that what is important about a language is the way the words interrelate to each other. For example, the words 'bounce' and 'bounces', 'discover' and 'discovers', and 'joke' and 'jokes' interrelate with 'I', 'you', and 'it' in predictable ways: 'I bounce', 'it bounces', 'you joke', etc.

Saussure's ideas were later applied to other areas of study. Most notably, Claude Lévi-Strauss (1908–2009) applied structuralism to mythology and anthropology, arguing (somewhat controversially) that underlying all mythology is the idea of two conflicting ideas, such as animal husbandry and agriculture, and their resolution (Lévi-Strauss, 1958, 1963).

We can now return to the problem of how Bryson attempted to give consideration to the 'material'. His proposed method for art history included the notion of realism. He noted that realism is often seen in relation to Pliny's account of the competition between artists Parrhasius and Zeuxis that we saw earlier. Bryson argued that there is a problem with this idea of realism. He wrote:

> Husserl's remarks concerning the sciences developed out of the natural attitude invite direct application to painting, at least as theorised in the account that stretches back in time from Francastel to Pliny. The world is pictured as unchanging in its foundation, however much its local appearance may modify through history; history is conceived of here as an affair of the surface, and, so to speak, skin-deep.

(Bryson, 1983, p. 5)

Bryson gave an example of how this essential reality, and the resulting 'Essential Copy', is something of a construction:

> While the image of a Roman family such as that of Vunnerius Keramus (a Roman portrait of a family) seem to state the timelessness of the human body, and would appear to confine the province of change to the limited margin of costume, the historical reality to which the figures in the image belong is precisely that which the image brackets out. The power of the image in this way to evoke an ahistorical sense of human reality, and in particular a sense of the culturally transcendent status of the body, is extreme.

(Bryson, 1983, p. 5)

Bryson thus argued that the Roman portrait is not really timeless, but is in fact constructed of elements that are conventional and not ‘culturally transcendent’. Furthermore, he argued that the underlying structure of the conventionalism is hidden, and thus the picture’s timelessness is something of an illusion.

Bryson developed this idea of realism in depth. He argued that realism, i.e.

> ‘the effect of the real’ consists in a specialised relation between denotation and connotation, where connotation so confirms and substantiates denotation that the latter appears to rise to the level of truth.
>
> (Bryson, 1983, p. 62)

Newall notes that by denotation Bryson means a ‘well-established and unequivocal symbolism’ and by connotation he means ‘a less sure relation, unfixed by any established iconography’ (Newall, 2011, p. 216). According to Bryson, ‘connotation’ allows ‘denotation’ to be ‘bracketed out’, or in other words less clear and fixed symbolism draws attention to the clarity of the fixed symbolism. Furthermore, according to Bryson, connotation supports the realism of denotation: he says that ‘following the wilful logic of realism, connotation thus serves to actualise its partner: because I believe in the connotation, I believe that the denotation is also true’ (Bryson, 1983, p. 65).

We can see how Bryson’s notion of realism fits in with his observations about the Roman portrait above. We noted that the picture is constructed of elements that are conventional and not ‘culturally transcendent’, but that the structure of the conventions is hidden. According to Bryson’s theory of realism, the picture’s ‘denotative’ elements, for example the basic structures of faces, are clear, whereas the 'connotative' elements, for example the nature familial relationships, are not clearly defined. The only exception to this is the clear denotative element of the costumes, which Bryson argues is thus the only element that situates the picture in time.

We might have a number of objections to Bryson. Firstly, there is the idea of the 'ahistorical sense of human reality', that Bryson argues is at the heart of our sense of realism. He writes that 'the Plinian account is that the real [is] a transcendent and immutable given' (Bryson, 1983, p. 5), and it may well be the case that many have seen realism in this way, but is it true that we generally see the 'real' in this fashion? In fact, we could argue that the opposite is the case. The period clothing of the Roman family sets the picture in context, making them appear as a 'real' family, whereas, for example, the nudity of gods and goddesses in Renaissance paintings make them appear more timeless, but also outside of the human realm, and thus less 'real' (Bull, 2006).

Secondly, and importantly for us here, Newall argues that Bryson's ideas of the relationship between denotation and connotation do not provide a guarantor for realism. He writes:

> Consider the word 'BANK', printed in Times New Roman capitals. The word, of course, denotes a financial institution, a bank. The font in which it is printed connotes a range of qualities, including tradition, continuity and stability – all qualities considered desirable in a bank. The qualities the font connotes thus can serve to underwrite in the reader's mind the credibility of the bank. The use of connotation in this way is a powerful design tool. A sign featuring the inscription 'BANK' is more likely to inspire customers' confidence than the sans serif, italicized inscription, '*BANK*', which connotes a very different set of qualities, such as modernity, change and dynamism, that sit poorly with

> the impression a bank is likely to want to project. Connotation, in this example, operates in just the way Bryson describes – it confirms and substantiates denoted meaning. But it is equally clear that there is nothing realistic, or even pictorial, in this example. The use of connotation to confirm and substantiate denoted meaning does not generate realism.
>
> (Newall, 2011, p. 216)

Thus Bryson's ideas of realism do not account for the facet of pictorial realism that distinguishes it from language, namely that languages are based on arbitrary notions of signs. For example, languages use, say, 'cat' or 'chat' for four-legged domestic felines, and 'dog' or 'chien' for four-legged domestic canines. Pierce's semiotics contains a solution to this, namely the idea of the 'icon,' a sign that unlike 'dog' or 'cat' shares visual features with that which it represents, but Bryson rejected Pierce's ideas, which he argued were like Gombrich's ideas in that they were based on the idea of the 'Essential Copy' (Bryson, 1983, p. 53). Bryson instead chose a modified form of Saussure's ideas, which is based on the essentially arbitrary nature of the sign (Bryson, 1983, p. 84).

We should note, however, that Bryson attempted to account in other ways for the physical element of the pictorial sign, namely the fact that the sign in painting notably relates to objects in the physical world. Bryson argued that it is the reduction of all theoretically possible signifiers to those permitted by the 'discourse' of material conditions that produces the materiality of the sign (Bryson, 1983, p. 84). Thus realistic pictures of clouds in a particular culture are those pictures of clouds with realistic features that a culture could produce: not fictitious features (pink clouds with blue spots), but in Constable's time features such as those seen in cirrus and cumulonimbus clouds, and in other times various white or grey shapes in various arrangements.

Bryson was clearly aware of the problems with the application of semiotics to visual art. He wrote that 'as the most material of all the signifying practices, painting has proved the least tractable to semiology's anti-materialistic proclivities' (Bryson, 1983, p. 85).

Indeed, such proclivities would become common in art history as semiotics became more common. An example of this problem with realism when using semiotics can be seen in following quote by art historian Griselda Pollock:

> When children first draw faces they tend to draw a circle, put the eyes at the top and the mouth at the bottom. Later we are taught that to make a face look like a human face one must place the eyes above the median line allowing for forehead and curve of the skull. The 'Wilding face' [Rossetti, *Regina Cordium,* 1866] **refuses this convention**. There is no forehead, only curving wings of hair directly above the brows with a curved parting running up the skull. This makes it difficult to read this as a forehead and puzzling because to see that much of the skull we should be above the model looking down. Yet the figure's gaze is level; because of the parapet setting the viewer is notionally below the painted figure. This abstracted or schematized quality does not disturb; indeed it takes some seeing. That is does not seem **grossly unnatural** is evidence of the fact that what we are consuming pleasurably is an artistically imposed order not a depiction of a human one.

(Pollock, 1988, Intro 2003, pp. 183–184), my emphases

The contradiction in this is that Pollock describes the positioning of the eyes on the median line as a 'convention', but then goes on to discuss

Rossetti's depiction as 'grossly unnatural'. If the placing of the eyes at the median line is only a convention, then it can hardly be described as natural. For Pollock's argument to hold there has to be a natural, or resembling, depiction for Rossetti to be deviating from. The tendency towards conventionalism in semiotic writing often leads to arguments such as Pollock's, that would otherwise be sound, to collapse logically.

Bryson would eventually become critical of the whole project of using semiotics to explain realism, and as we will see he would eventually change his position radically. He wrote:

> The basic tenets of semiotics, the theory of sign and sign-use, is anti-realist. Human culture is made up of signs, each of which stands for something other than itself, and the people inhabiting culture busy themselves making sense of those signs. The core of semiotic theory is the definition of the factors involved in this permanent process of sign-making and interpreting and the development of conceptual tools that help us to grasp that process as it goes on in various arenas of cultural activity.

(Bal & Bryson, 1991, p. 242)

We see here Bryson noting the major problem of the semiotic approach to art. Semiotics reintroduces the idea of the sign into art, but this only reintroduces the idea of the social construction of painting; it does not really deal with the 'materiality' of painting. It re-socialises procedures such as the painting of the sky; for example, semiotics allows us to examine the way different societies have different interests when depicting the sky; in Constable's society, for example, meteorology fascinated many, so Constable incorporated the latest taxonomy into his paintings, while the Ancient Egyptians hardly painted the sky at all, only occasionally personifying it as the Sky Goddess Nut. However, semiotics does not deal with the actual physical nature of clouds as it relates to painting: it only describes which material forms happen to occur in a particular society and culture.

We might ask why Bryson did not simply return to Gombrich's position. To answer this, let us look carefully about Gombrich's ideas concerning Constable's paintings of clouds. When an artist paints clouds, he or she necessarily leaves elements out; one can hardly paint each and every strand of cirrus in its precise location. Gombrich's ideas are based on the assumption that meteorological classification will bring us closer to the 'true' form of clouds, rather than simply presenting another, though perfectly reasonable, way of viewing them. Bryson argues that Gombrich's idea of realism is something artist slowly edges towards, that the artist 'adjusts the schema which tradition has supplied until the image on the canvas corresponds to the scene before his eyes' (Bryson, 1983, p. 44).

Bryson remained unconvinced about this idea. He noted the 'fundamental groundlessness of being that is a hallmark of modern Western philosophy … that runs through the writings of Heidegger, Sartre, Wittgenstein, Derrida, and Lacan' (Bryson, 2003, p. 12). This 'groundlessness' is antithetical to Gombrich's idea that over time painting, by repeatedly adjusting schema, can produce the scene one sees. Bryson would continue to refer to such viewpoints as 'archaic' and 'coercive':

> In the older, archaic picture of the coercion of the cultural subject (Marx, Freud, technological determinism) it was assumed that the subject could be mapped, interpellated, and manipulated—that the subject of ideology could be made uniform and acquiescent.

(Bryson, 2003, p. 18)

We will deal with some of these issues of realism later in the thesis, but we will here consider how contemporary neuroscience might find a solution to Bryson's dilemma. Onians notes that the biological, in the form of neuroplasticity, might be the way forward, and suggests that when Bryson closed the door on what Bryson called Gombrich's 'Essential Copy', he also closed the door to a solution to his problems, namely cognitive psychology. Onians writes that '"discourse", "the unconscious", "intertextuality", and "embodiment", could all find sustenance in the new neuroscience' (Onians, 2016, p. 4).

Onians also notes that Bryson eventually recognised this (Onians, 2016, p. 4). We might note a recent quote by Bryson:

> And as in phenomenology, the emergence of the world within human consciousness is the result of a cooperation between self and world in which both self and world co-inhabit and mutually constitute each other, through a perpetual crossing-over or chiasmus where the world 'out there' is in fact built by consciousness 'in here,' but by an embodied consciousness, a mind that is also a part of material reality, part of the world itself.

(Bryson, 2003, p. 11)

If the sign itself is dematerialised, then it becomes difficult to find a relationship between the signifier and that which is signified. As noted above, Bryson's original solution, being the discourse that produces the reduction of the possibilities of signification in a particular culture, did not actually deal with the problem of the dematerialisation of the sign; as we saw in the 1991 quote Bryson observed that it only re-socialised the choice of signifier.

The notion of an ‘embodied consciousness’ thus re-materialises the sign from the other end, as it were. The sign itself becomes fully physical, and furthermore the process whereby the image that falls on the retina, is processed in the brain, and then directs the hand of the artist on the canvas, is a fluid and fully physical process.

Thus for Bryson, biology, and its child, neuroscience, provides a way of re-materialising the sign without the issues he found in Gombrich, namely the problem of the teleology of perceptualism in art: that art’s purpose is to chase an essentialist core of reality. Bryson also notes that this subjectivity does not have to be incompatible with the science that is the mother of his new approach: he notes that his favoured view of history

> is non-teleological, in the same way that Darwin is non-teleological: what drives the evolution of subjectivity is conflict between competing systems.

(Bryson, 2003, p. 17)

The understanding of neuroscience thus provides a biological basis for the study of visual culture, allowing us to make more general statements about visual cultural production and reception. The application of contemporary neuroscience can therefore be said to widen the door to the study of art and visual culture in general, many aspects of which will be examined in this thesis.

(Agursky, 1997) (Alberti, 1435) (Ibn al-Haytham, 1011–1021) (Aristotle, c.335 BCE) (Bal & Bryson, 1991) (Baxandall, 1972) (Baxandall, 1980) (Berlyne, 1960) (Bryson, 1983) (Bryson, 2003) (Bull, 2006) (Chevreul, 1855) (Cochrane, 2014) (De Saussure, 1916, 2011) (Düchting, 1999) (Edgerton, 1975) (Edgerton, 2009) (Euclid, c.300 BCE) (Finger, 1994)

(Gombrich, 1960) (Gombrich, 1979) (Helmholtz, 1881) (Hogarth, 1753, 1997) (Kim & Blake, 2007) (Lévi-Strauss, 1958, 1963) (Livingstone M. , 2002) (Livingstone, Pettine, Srihasam, Moore, Morocz, & Lee, 2014) (Locke, 1690) (Matchotka, 1980) (Messinger, 1998) (Mulvey, 2009) (Munsell, 1905) (Newall, 2011) (Onians, 2008) (Onians, 2016) (Peirce, 1991) (Podro, 1982) (Pollock, 1988, Intro 2003) (Popper, 1945) (Rewald, 1956) (Riley, 2009) (Snow, 1959).

THE VISUAL SYSTEM

> No, Cassius; for the eye sees not itself,
> But by reflection, by some other things.

Brutus, *Julius Caesar,* William Shakespeare (Scene II, Act I)

We can note then that the twentieth century saw a huge rise in the study of the human visual system. We will here summarise this knowledge. Our examination will start with the knowledge of the most obvious structure involved in vision, namely the **eye**. Light is detected in the eye by a surface known as the **retina**. The retina contains cells, known as **photoreceptors**, that contain chemicals that turn light into electrical signals that then travel up the **optic nerve**. In the centre of the retina is an area known as the **fovea**, which has cells that allow for the sharpest vision. The light is focused onto the retina by two lenses, the outermost one known as the **cornea**, and an inner one known as the **lens**. The cornea is fixed in shape, but the shape of the lens can be modified by muscles, so that the focus of the light can be changed. The iris is the coloured part of the eye, with muscles that can vary the shape of the hole in its middle, the pupil. The varying size of the pupil allows the amount of light entering the eye to vary (Figure 2, p. 50).

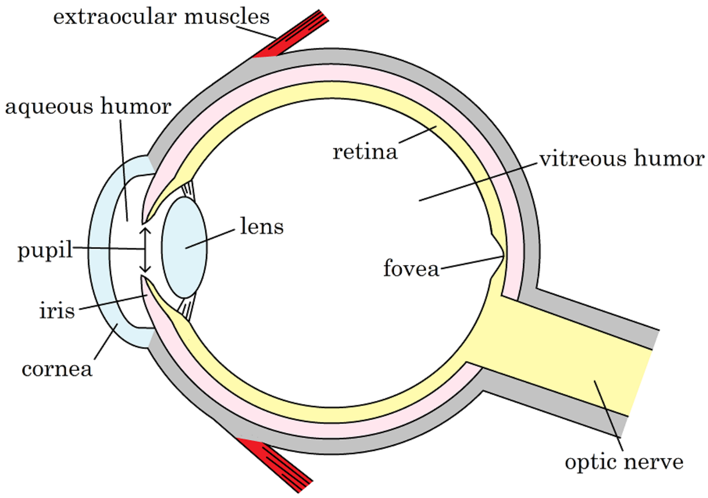

Figure 2 Cross-section through the human eye. Diagram by the author.

Muscles on the edge of the eye allow the eye's direction to be changed rapidly. The eye is in fact hardly ever still, changing direction at least three times a second, in what are called saccade movements (Rose & Dobson, 1985, p. 62).

The photoreceptors are of two types: **rods** and **cones**. Rods are mostly sensitive to greeny-blue light, and cannot differentiate between different colours. Their main strength is that they are extremely sensitive, so are useful in the dark; they are used primarily in motion detection. Cones are less sensitive, but can detect many different colours. Cones are mainly for identification. As rods are used primarily for motion detection, and this thesis is primarily about painting, we will instead focus on the cones.

Light has both wave and particle properties. Different colours are distinguished by their wavelengths. The wavelength of visible light is in the range of 390 to 700 nm. ('nm', all lowercase, short for nanometres, or millionths of a millimetre). Going from short to longer wavelengths, the spectrum starts with blue shades, goes through turquoise, green, lime, yellow, and orange shades, and finishes with red shades.

There are three types of cones, known as **S cones**, **M cones** and **L cones**, each type sensitive to a different range of wavelengths. The S cones are sensitive to shorter wavelengths, at the violet end of the spectrum, M to medium wavelengths, which peak at green light, and L to long wavelengths, at the red end of the spectrum.

It is that there are three types of cones that colour vision becomes possible. The individual types of cone do not in themselves allow for colour vision. The L cone will produce the same signal if either pillarbox red or yellow light falls on it. What allows colour vision is that different colours can activate more than one type of cone. Yellow light, for example, activates the M and L cones more or less equally, green activates mainly the M cone, while red activates the L cone while hardly activating the other cones at all. (My reason for the term ‘pillarbox red’, and also ‘royal blue’, will become clear later on.)

We can see this in Figure 3 (p. 52). The L cone stimulated on its own gives pillarbox red light, the L and M together gives yellow light, the S and M together gives cyan blue, etc. Note that intermediary colours are made by varying the stimulations: a small stimulation of the L cones and a larger stimulation of the M cones would give orange; a small stimulation of the M cones and a larger stimulation of the S cone will give a turquoise, etc. Notably, we must deal with the case of the L and S cones being stimulated. There is no spectral colour that can cause this stimulation, it only occurs with mixtures of red and blue light. We nevertheless perceive such mixtures as a colour, known as magenta (shown at the bottom of the diagram).

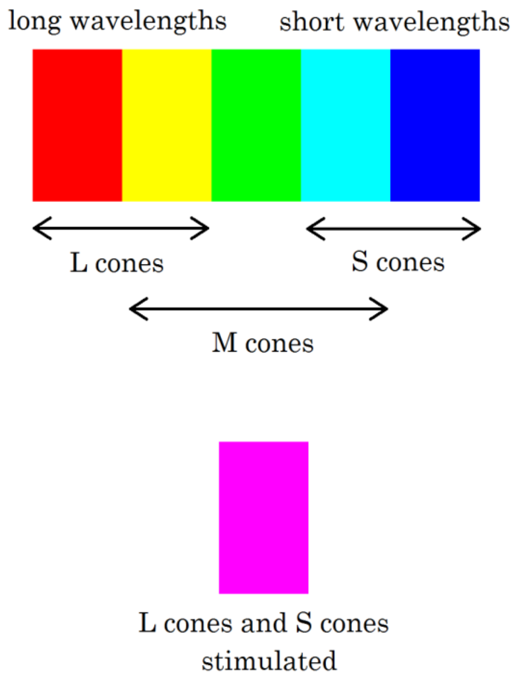

Figure 3 Simplified diagram of the wavelengths stimulated by the different cones in the eye. Diagram by the author.

Knowing about cones explains how television screens and artists are able to mix different colours. The properties of materials means there are two different types of colour mixing, known as **primary** and **secondary**. We will examine this in greater depth later, but for the moment we might note that due to there being three colour photoreceptors, three colours can be used to make the colours on a TV screen, and a basic artist's palette can be formed (Figure 4, p. 53).

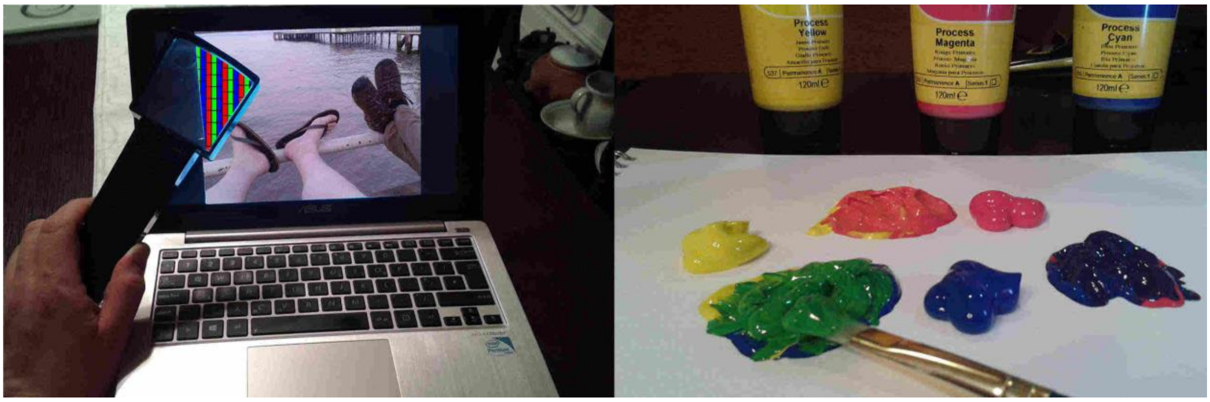

Figure 4 Primary (left) and secondary (right) colour mixing. On the left we see how the screen is made up of a mosaic of pillarbox red, green, and deep blue rectangles that mix in the eye. On the right we see how yellow, magenta and cyan paint can be mixed to make other colours. Photographs by the author.

The signals that pass from the cones up the optic nerve trigger cells that measure the response to light from the cone cells. It is important to note that it is not the case that one cone has one connecting fibre in the optic nerve feeding to one measuring cell. Instead, each cell that detects responses from the eye is channelled by signals from a number of cones. The collection of cones in the eye that trigger a brain cell is known as that cell's **receptive field**. Receptive fields vary in size, notably those involved in light detection being larger than those involved in brightness detection. Receptive fields are, in fact, a feature of nerves in general; finding the exact location of pain is often exacerbated by the pain nerves feeding into a single cell in the brain.

The difference between the sizes of the receptive fields is important. That the receptive fields for colour are larger than the ones for brightness makes brightness more suitable for detailed work, explaining why writing and architectural plans are mostly in black and white, as the differences in brightness are strongest in black and white.

The signals from the three types of cones, together with the signals from the rods, travel up the optic nerve into the brain (Figure 2, p. 50, Figure 6, p. 56). In the **midbrain**, and more specifically the **lateral geniculate nucleus**, the signals from the eye trigger cells that direct the eye signals towards the back of the brain. The '**LGN**' is thus often compared to a relay station.

The mechanism of the cells further on in the chain of vision in the retina and the midbrain is of particular interest. The cells, known as **centre-surround** cells, detect lines and edges. This mechanism was discovered by measuring the voltage of the centre-surround brain cells when light is shone in the eye. Figure 5 (p. 55) explains how this occurs. The diagram, highly simplified, shows a receptive field of a particular centre-surround cell. The plus and minus signs represent photoreceptors in the eye. The 'plus' photoreceptors cause the centre-surround cell to produce a positive signal if light hits it, and the minus photoreceptors cause the centre-surround cell to produce a negative signal if light hits it. The plus photoreceptors are concentrated in the centre of the receptive field, the minus in the periphery. The diagram shows what happens if various patterns of light hit the receptive field. We shall work from the top left to the bottom right. Picture 1 shows the field with no light hitting it. The field produces a signal of 0. Picture 2 shows a single point of light in the outer area of the receptive field. The signal produced is −1. Picture 3 shows a single point of light in the inner area of the receptive field. The signal produced is +1. It is with lines and contours that we see the main stimulation of the centre-surround cells. The light in Picture 4 and Picture 5 both produce signals of −3. It is important not to get too carried away by the neatness of this, for some lines do not produce strong signals. Picture 6 shows what happens when a line of light passes through the centre of the cell: the signal produced is −2 +2, which equals 0. Edges also produce strong signals. The light in Picture 7 produces a signal of −3, the light in Picture 8 produces a signal of +3 (= +9−3), and the light in Picture 9 produces a signal of 0 (= +5−5). Finally, the light in Picture 10 produces a signal of 0 (=+10−10).

From this we see what the centre-surround signals detect. Small points of light, as in Picture 2 and Picture 3, produce small signals. Total coverage of light, as in Picture 10, produces no signal. Lines and edges, however, as seen in the middle two rows of the diagram, produce substantial signals. We should note, however, that sometimes the visual system fails, as we saw in Picture 6 and Picture 9, which produce no signals.

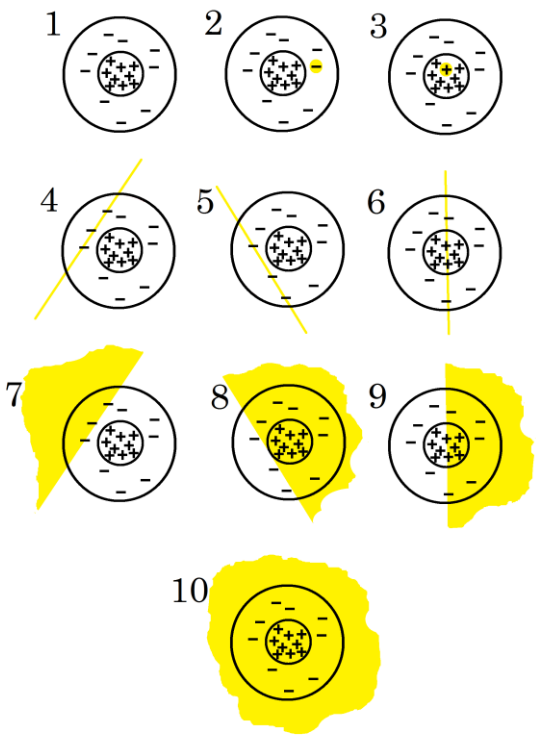

Figure 5 Receptive fields of centre-surround cells. Signals produced by centre-surround cells due to stimulation by light, with light shown as shaded areas. Values of signals produced: Picture 1: 0, Picture 2: −1, Picture 3: +1, Picture 4: −3, Picture 5: −3, Picture 6: 0, Picture 7: −3, Picture 8: +3, Picture 9: 0, Picture 10: 0. Diagram by the author.

We see, then, that the centre-surround cells detect lines and edges rather than points or areas of light. We should note, however, that Picture 4 and Picture 5 produce the same signal, even though the lines are in different directions. This can also be seen with Picture 7 and Picture 8. The question remains of how the brain detects the orientation of lines and edges. We shall find the answer to this when we look at the next stage of visual processing, which happens in the **visual cortex**.

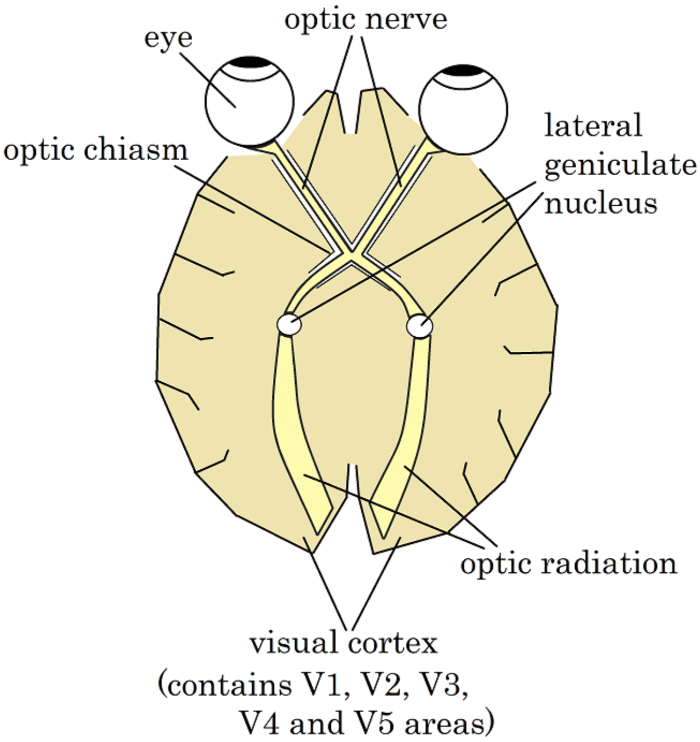

Figure 6 Transverse basal (cross-section from below) view of the human brain, showing the visual system. Diagram by the author.

The signals from the LGN travel to the visual cortex, which, perhaps oddly, is at the back of the brain (Figure 6, p. 56). The visual cortex is possibly the most important area of visual processing in the brain. It is divided into a number of areas, known as **V1** (also known as the primary visual cortex), **V2**, **V3**, **V4**, and **V5**. Each of these areas processes various parts of vision, though the extent to which each area specialises and overlaps in function with other areas is controversial. Generally, though, the V1 area handles initial processing (which we will examine in detail below), the V2 and V3 areas in more complex form processing, the V4 handles colour processing, and the V5 handles motion detection.

Studies into the V1 area explain how the brain detects the orientation of lines and edges. The signals from the centre-surround cells are channelled into V1 cells in lines of adjacent receptive fields. If a line or edge of light hits all these lines it will stimulate the particular V1 cell, via the centre-surround cells, very strongly. Each V1 cell, then, detects a particular orientation of line or edge of light.

This importance of lines and edges in the brain explains an important feature of art. This feature is how we can perceive line drawings, when the world in general is not made up of lines. The visual system detects lines with the same equipment as it detects edges, and is indeed constructed to detect edges and boundaries.

At this point the brain's processing of information becomes more complex. The signals from the V1 area pass through the other areas of the visual cortex, and from there into the rest of the brain. The processing of these areas is highly complex, processing object recognition, pattern recognition, and many other parts of vision, often spread over many areas of the brain. We shall examine some of these higher properties, as well as the more basic processes, in more detail within the thesis.

We might, though, note an important overall property of the higher visual system. The visual system is divided largely into two pathways, the **dorsal**, or **where** stream, and the **ventral**, or **what** stream (Figure 7, p. 58). Again, it is important not to get too carried away with the neatness of this, as mental systems often overlap, but visual processing is largely divided up into a stream that travels to the upper brain that deals with the position of objects (dorsal/where), and a stream in the lower brain that deals with the identification of objects (ventral/what). The two streams notably have varying properties. The 'what' stream deals with identification, tends to be relatively slow, and is normally a conscious process, while the 'where' stream guides motion, tends to be relatively fast, and the organism is often unconscious of its effects on behaviour.

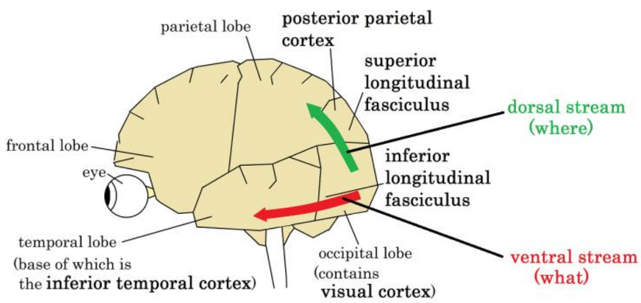

Figure 7 Lateral (side) view of the human brain, showing the visual system. Diagram by the author.

(Bisti & Maffei, 1974) (Blake & Sekuler, 2006) (Clay Reid & Martin Usrey, 2013) (De Valois & De Valois, 1975) (Eysenck & Keane, 2010) (Gazzaniga, Ivry, & Mangun, 2009) (Gregory, 1977) (Hubel & Wiesel, 1959) (Issa, Trepel, & Stryker, 2000) (Livingstone M. , 2002) (Pomerantz, 1981) (Rose & Dobson, 1985).

USE OF PSYCHOLOGY IN THIS THESIS

Before outlining the precise aims and structure of this thesis, we will examine a few preliminary points.

Firstly, let us note how psychology is used in this thesis. I use a total of twelve applications of psychology to art. These are:

A preliminary examination of the role of the visual system in art ('Against Simple Resemblance: Saccades, Screen Colours, Screen Resolution, and the Cornsweet Illusion (Application of Psychology to Art 1)' p. 81), theories of attention ('Multiple Spotlights' p. 97), physiological and psychological theories of colour ('The Reliability of the Visual System: Colour Vision (Application of Psychology to Art 3)' p. 109), theories of recognition ('Recognition-by-Components (Application of Psychology to Art 4)' p. 162), theories of visual acuity ('Decomposition and Recomposition: Scales (Application of Psychology to Art 5)' p. 210), theories of nerve reception ('Decomposition and Recomposition: Receptive Fields (Application of Psychology to Art 6)' p. 245), theories of culture ('The Selection of Features in the Creation of Pictures: Perspective, Cross-Cultural Psychology, and the Period Eye (Application of Psychology to Art 7)' p. 250), theories of visual ordering ('Conflicts in Interpretation: Gestalt Conflict (Application of Psychology to Art 8)' p. 277), theories of pattern recognition ('Pattern Recognition, and Decorative Art (Application of Psychology to Art 9)' p. 294), theories of semantics and syntax ('Semantics and Syntax, and Figurative Art (Application of Psychology to Art 10)' p. 305), and theories of motion detection 'Appendix. Motion Detection in Cinema (Application of Psychology to Art 11)' (p. 322).

We will also need to clarify some of the terminology surrounding this area. Firstly, there is the term psychology. This word is sometimes used to mean solely scientific experimental psychology, hence excluding writers such as Freud, but I will use it to mean any academic writing on the psyche. I will also make a distinction between psychological interpretations by art historians, and the application of psychological research to art history. An example of the former is Baxandall's 'period eye' technique, in which cultural sources such as engravings are used to reconstruct how humans in a given period perceived qualities such as space and colour; an example of the latter is Gombrich's *Art and Illusion*, which uses theories originating in psychology. Following Podro, I shall refer to the former process as psychologism, and the second as an application to art history of psychology (Podro, 1982, p. 178).

Furthermore, the application to art history of what I have termed psychology must include teasing out the different but intertwining strands within this area. One is the distinction made between applications of psychological research by art historians, and psychological research on art by psychologists. Further to this is the scope of the study of psychology itself. The main psychological approaches are cognitive, behavioural, neuro-biological, phenomenological and psychoanalytic. Cognitive psychology is perhaps the most appropriate for the study of perspective, due to perspective being largely concerned with the mind's processing of spatial data; hence it will be the main focus of this study. However, psychological approaches tend to overlap, so other approaches might be useful. We should furthermore note the varying methodologies of psychology. Behavioural psychology and phenomenological psychology utilise experimentation; neuro-biological psychology utilises brain imaging techniques, dissections and biochemistry; cognitive psychology utilises a combination of these techniques, and adds the use of computer modelling; and psychoanalysis utilises intensive case studies (Walsh, Teo, & Baydala, 2014).

THESIS STRUCTURE

The thesis develops a theory of art centring around depiction. It shows that pictures are arrangements of visual features of a subject, that the visual features of a picture resemble the visual features of the subject, that artists select relevant features when making pictures, and that artists may distort these features to varying degrees. The thesis also argues that there is another important process the visual system brings to picture making, that of ordering a picture's elements.

The thesis argues that pictures involve three elements: that of the subject itself (e.g. its shape and boundaries), the properties of the light that carries the information about the subject to the eye (e.g. atmospheric distortion), and the properties of the visual system (e.g. the three types of cell that detect colour). This was summed up by philosopher Nelson Goodman (1906–1998) when he said that a picture is 'the Duke of Wellington as he looks to a drunk through a raindrop' (Goodman, 1968, p. 7).

Most importantly, the thesis uses psychology to explain these processes. I argue that the properties of the visual system allow the various forms of depiction to occur.

Chapter 1. Resemblance: Do Pictures 'Look Like' their Subjects? (p. 65) begins with a basic theory of depiction, namely that a picture 'resembles' its subject. It goes on to examine two challenges to this, firstly that the visual system may distort the information it receives from its environment, and secondly that the visual system may misrecognise the features of its environment. The chapter concludes that the visual system largely does not either distort information or misrecognise objects, but that the possibility that it can means that a picture may distort its subject, and that furthermore this is a key feature of depiction.

'Resemblance and the Debate about Depiction' (p. 66), the first section of *Chapter 1*, examines the concept of realism. The first problem examined is that the word 'realism' is not quite the right one for the concept we are dealing with, and we will see how 'resemblance' is better, leading us to develop a better understanding of resemblance.

'Against Simple Resemblance: Saccades, Screen Colours, Screen Resolution, and the Cornsweet Illusion (Application of Psychology to Art 1)' (p. 81), the second section of *Chapter 1*, examines the fact that it is not always necessary for a picture to send the same array of light through the pupil as the eye does itself. For example, when passing through the eye mixtures of pillarbox red light and green light appears to be yellow, so an image on a television screen might appear to resemble a daffodil, but may be composed of very different wavelengths. We will see how knowledge of the visual system aids us in understanding such phenomena.

'Distortion Beyond the Primary Visual System: The Multiple Spotlights Theory of Attention (Application of Psychology to Art 2)' (p. 97), the fourth section of *Chapter 1*, further examines the notion of visual distortion that we saw with Panofsky. We examine a psychological theory of attention, namely multiple spotlights, that explains how this distortion can occur.

'The Reliability of the Visual System: Colour Vision (Application of Psychology to Art 3)' (p. 109), the fifth and final section of *Chapter 1*, examines the issue that is immediately brought up by our pillarbox red/green daffodil. This is that our visual equipment can be unreliable, for we could mistake an object that throws off pillarbox red and green light for a yellow object. I will argue that in general our visual equipment is in fact reliable.

Chapter 2. Informativeness: Going Beyond Simple Resemblance (p. 161) begins the examination of the issue that pictures tend to include certain features of their subject while omitting others. It posits an explanation for this, from the theory of informativeness. The chapter shows that a picture presents a particular *selection of features* of its subject, features which may be distorted in the picture for various reasons.

This chapter adds to the observations of the previous chapter by incorporating the notion of informativeness. This is done by introducing the theory of recognition-by-components, to adumbrate the idea that pictures present a subset of the properties of the array of light that enters the eye.

Chapter 2 also examines applications of this approach to understanding art, namely the work of Leonardo da Vinci and Hieronymus Bosch, and the analyses of Heinrich Wölfflin. The overall conclusion of *Chapter 1* and *Chapter 2* will be a new understanding of depiction, which will argue that a picture resembles features of its subject matter. A picture may leave out certain features, and modify or distort others. The features chosen by the artist provides the information about the subject matter that the artist feels is relevant. The modifications and distortions either aid the presentation, or distort the subject matter.

Chapter 3. Features of Depiction: What an Artist Leaves In, Takes Out, and Distorts in a Picture (p. 208) further examines the problem introduced in *Chapter 2*, namely explaining how and why artists can distort or leave out features of the subject of a picture. *Chapter 3* uses theories of psychological 'scales' and the properties of receptive fields to develop a theory of the decomposition, processing, and recomposition of visual information and how it applies to depiction. Furthermore, it examines the role of culture in this process.

Chapter 4. Order: Organising and Finding Patterns in Pictures (p. 276) addresses the issue of how depiction and order interact, to help us understand how depiction not only involves resemblance, distortion, and informativeness, but also involves organising principles.

Chapter 4 also elaborates further on how the visual system's abilities in the decomposition of elements of a stimulus allow the varieties of depiction to occur that we saw in *Chapter 3*. We see how the visual system decomposes visual stimuli into component features, and that the visual system's attempt always to interpret a stimulus in one way or another allows artists to (a) leave features out, and (b) distort features. It shows that this is because the visual system's attempts to find a coherent interpretation of a stimulus cause it to compensate for (a) the missing features, and (b) the distorted features.

Outside of the main body of the thesis is **Appendix. Motion Detection in Cinema (Application of Psychology to Art 12)** (p. 322). The thesis is mainly concerned with painting and drawing, but most visual information is moving, and the twentieth century heralded the widespread interest in the moving image. This appendix examines an example of how psychology can be used to explain techniques used by filmmakers.

CHAPTER 1. RESEMBLANCE: DO PICTURES 'LOOK LIKE' THEIR SUBJECTS?

RESEMBLANCE AND THE DEBATE ABOUT DEPICTION • AGAINST SIMPLE RESEMBLANCE • MULTIPLE SPOTLIGHTS • COLOUR

INTRODUCTION

This first chapter examines the notion of resemblance. The idea that a picture 'looks like', or more precisely shares visual properties with, its subject is intuitive and has a long history. However, the situation is complicated. This chapter examines a range of evidence, including ideas from the 'The Visual System' section of the *Introduction* (p. 49), theories of attention, and John Hyman's arguments about colour, which will lead to a firm understanding about the way that both pictures, and our perception of reality itself, can be distorted.

The conclusion we will arrive at is that the visual system may on occasion present us with a distorted view of reality, but that nevertheless our perception of reality is generally reliable. This will allow us to arrive at a preliminary understanding of depiction, that a picture records the path of light and electric signals as they pass from the subject matter (as light), through whatever is in-between the subject matter and the viewer (as light through air, glass, etc.), and through the visual system (as electrical signals). Nevertheless, the possibility of the visual system's distorting of reality presents artists with the possibility of distorting images while still achieving recognition. These distortions have a variety of uses, including improving the presentation of images for various uses, including diagrams.

This will allow us to extend our understanding of depiction to include less realistic pictures, such as those of Picasso.

The chapter is divided into four sections. 'Resemblance and the Debate about Depiction' (p. 66) delineates terms such as 'realism', 'lifelikeness', and 'resemblance'. 'Against Simple Resemblance: Saccades, Screen Colours, Screen Resolution, and the Cornsweet Illusion (Application of Psychology to Art 1)' (p. 81) examines inconsistencies in the idea of resemblance, and uses knowledge from the science of vision to explain these. 'Distortion Beyond the Primary Visual System: The Multiple Spotlights Theory of Attention (Application of Psychology to Art 2)' (p. 97) examines what theories of attention might teach us about visual distortion. Finally, 'The Reliability of the Visual System: Colour Vision (Application of Psychology to Art 3)' (p. 109) examines the current debate about colour vision, and what can be learned from these arguments about the reliability of the visual system.

RESEMBLANCE AND THE DEBATE ABOUT DEPICTION

> The fixture of her eye has motion in't,
> As we are mock'd with art.

Leontes, *The Winter's Tale,* William Shakespeare (Scene III, Act V)

As we saw in the *Introduction* (p. 18), the debate about depiction has concerned art historians and philosophers since Gombrich, and indeed for thousands of years. Thus before we can proceed with our investigation of the psychology of art, we need to examine the debate surrounding this topic. More so, we will need to delineate exactly what features of art we are going to examine in this thesis. One aim in art is realism, but is it realism that we want to deal with here, and furthermore what exactly do we mean by ‘realism’ anyway? Leontes was overwhelmed with the realism of the statue of Hermione, but of course not all art is realistic: he might have reacted very differently to a Picasso portrait of his wife. We thus might note that realistic art forms a subset of art in general.

The debate on the nature of art is wide, so it would be beyond the scope of a thesis such as this to examine theories of every type of artistic production. As a result this thesis will mainly be restricted to depiction, which since Gombrich’s 1960 book *Art and Illusion* has been a major focus for the discussion of the nature of art. However, I will also consider some decorative and abstract art, and I include an appendix concerning cinema, which demonstrates the possibilities of extending this debate to other media.

The main focus of this thesis is to examine the consequences vision science has for theories of depiction. Understanding such theories, however, will need to proceed along the lines it has historically. Ever since at least the time of the Parrhasios and Zeuxis story realism has been a major goal of art, so realism will be a major part of our discussion. It is, however, my aim to extricate this discussion from a focus on pictorial realism, and examine depiction in general.

In general I will be aiming to support a perceptual theory of depiction that incorporates elements of resemblance theory. I will support the argument that the visual system identifies features of its environment, such as shapes, including three-dimensional shapes, and colours. Art exploits this by presenting the same features in pictures, causing the visual system, in a special way, to misrecognise pictures as the objects depicted: something called ‘twofoldness’ by philosopher Richard Wollheim (1923–2003)

(Wollheim, 1968). Issues that will need to be dealt with around such a theory include the nature of this 'special way' of misrecognition. If we misrecognise George Stubbs's c.1762 *Whistlejacket* as a rather large rearing horse, why do we not run in terror from Room 43 of the British National Gallery, and then perhaps attempt to cool down in Room 41 by trying to join the working men in the river of Georges Seurat's 1884 *Bathers at Asnières*? If depiction is about recognition, what exactly is different about recognition in pictures than recognition in reality? The answer to this will have implications for theories of both pictorial realism, and depiction in general.

Furthermore, we must ask exactly how recognition is related to resemblance. We will see that some philosophers and writers on art, such as Dominic Lopes, would forefront recognition over resemblance, while others, such as John Hyman, would do the opposite. We will need to examine these, as well as other issues.

In this section, then, we will make a preliminary examination of the debates about depiction, including realism, which will be developed in more depth in the rest of the thesis. We will begin by examining the notion of 'realism' further, to arrive at a clearer definition of what we want to examine in this thesis. The word realism can mean different things. Consider, for example, *Slave Market*, an 1866 painting by Jean-Léon Gérôme (1824–1904) of an Arab slave market. Our first thought might be that it is startlingly 'realistic'. But what 'realism' are we talking about? Does realism mean that it accurately portrays the conditions of a slave market? We can imaging the misery and suffering of slaves in the Arab world and would be surprised if it was not very different from the idealised conditions depicted by Gérôme.

What, then, does 'realism' mean for us here? Firstly, then, we might distinguish it from what might be called social realism. For social realism it is not whether or not the figures in Gérôme's paintings of slave markets look like the models who posed in his studio, it is rather to what extent Gérôme idealised the practice of slavery in Arab countries. We can see how this notion of social realism can apply to media far removed from 'looking like' the subject matter, for example written descriptions. A written description of one of Gérôme's models might well also be realistic, if it carefully describes the texture of the model's skin, the colour and length of her hair, etc., and indeed a written description of an Arab slave market might be realistic if it described the degrading treatment of slaves in the Arab world. However, a written description of a model does not look like the model, or a description of degrading treatment, but rather looks like a series of rows of black lines and curves on a white background, or in other words it looks like a sequence of letters.

The property we can say we are looking at, then, might better be described by the term 'resemblance' (Sartwell, 1994, p. 6). We will see, however, that this notion of resemblance only takes us so far, and we will need to go beyond it, but it will be a good place to start. One way of thinking about resemblance is that a picture resembles its subject if it sends the same array of light through the pupil as would the subject itself. (Adapted from Goodman (Goodman, 1968, p. 11).)

An important point needs to be cleared up before we can proceed. Imagine a highly realistic painting of a unicorn, one in which the shininess of the horn, the glint in the unicorn's eye, and the sleekness of its mane are depicted as if in a photograph. We might say that the painting resembles the unicorn in that it sends the same array of light through the pupil as would the unicorn itself.

The obvious problem is that no eye has ever had the light from a unicorn passing through it, as there are no unicorns. Similar arguments can be made about the long-legged elephants in Salvador Dalí's lifelike pictures, or the bio-mechanoids in artist H. R. Giger's airbrushed designs for the film *Alien*. Such paintings cannot resemble their subjects, for there are no such elephants or xenomorphs in reality.

This problem is not, perhaps, difficult to solve. What we might say is simply that 'a picture resembles its subject matter if it sends the same array of light through the pupil as would the subject matter itself, if the subject matter were to exist'. Hence, if a unicorn, a super-long-legged elephant, or a xenomorph were to exist, it would send a particular array of light through the eye, and if a picture were to resemble the creature, it would send the same array of light through the eye.

We might next note another issue, that of an important stage in the path of light. The light, having been directed through the cornea and the lens, hits the retina. The retina converts the light into electric signals that can be processed by the visual system. The retina, then, acts in a similar way to a photographic plate, as in an old-fashioned camera. We might thus redefine our idea of resemblance to be a record of the 'retinal image', or the light from a subject that falls on the retina.

This all sounds well and good, but contains subtleties of reasoning that can lead the unwary astray that we should examine here. The primary motivations for adopting the idea of the 'retinal image' are that it neatens the concept of resemblance, it allows the notion of the subject matter sending the 'array of light through the pupil' to be delineated in a more precise way, and that it integrates the definition with a description of the visual system. If light from the environment falls on the retina, and if it is the retina that mediates between the light from the environment and the mind, then if an artist wishes to produce a realistic picture he or she should create one that causes the photoreceptors in the retina to be triggered in the same way that the subject being depicted would.

Though at face value this account of resemblance appears reasonable, there are two issues raised by it. Firstly, we should note that the retina is a curved surface, and thus any image that falls on it will be distorted curvilinearly. This issue requires some more detailed analysis, so we will examine this point later. Secondly, our account of resemblance is based on a tacit assumption whose ramifications are misleading. The subtlety lies in the question of where the viewer is placed in the scheme: is the viewer looking at the subject, or at his or her retina? We will see that if we choose the latter, grave errors can result. Many writers have, however, taken the latter view, and as John Hyman notes this idea of the mind viewing the retina has been common in the writings about art of the twentieth century. Psychologist Richard Gregory explicitly states:

> When an artist employs geometrical perspective he does not draw what he sees—he represents his retinal image.

(Gregory, 1977, p. 174), quoted in (Hyman, 2006, p. 227)

This viewer of the retinal image is often referred to as a 'homunculus', a little person who sits at the back of the eye looking at the retina as if watching television, an idea that dates back at least to René Descartes

(1596–1650) in the seventeenth century (Livingstone M. , 2002, p. 24) (Hyman, 2006, p. 225).

In order to understand the issues behind realism, it will be worth examining the historical background to the subject in more depth. One of the major themes of the Renaissance was the notion that art should be true to reality. The early historian of art Giorgio Vasari (1511–1574) argued that 'it was Giotto who opened the door to truth' (Vasari, 1568, p. 55), and furthermore related a probably legendary story that illustrates the importance that this truth had to the Renaissance:

> … when Giotto was still a young man in Cimabue's workshop, he once painted on the nose of one of the figures Cimabue had executed a fly that was so lifelike that when Cimabue returned to carry on with his work he tried several times to brush it off with his hand …

(Vasari, 1568, p. 80)

Vasari believed that this truth should extend to all areas of art, including the depiction of space:

> Filippo [Brunelleschi] made a careful study of perspective, which because of all the errors of practice was in a deplorable state at the time, and he worked for a long while until he discovered for himself a technique by which to render it truthfully and accurately …

(Vasari, 1568, p. 136)

Though Brunelleschi was one of the most important contributors to the development of linear perspective, the most notable theoretical discussion of this topic of the Renaissance was the 1435 treatise *On Painting* by Alberti. In this book Alberti, among treatments of all features of painting from human proportion to the depiction of horses' hair, summarised one of the most important techniques of spatial depiction that had developed over the course of the Renaissance: linear perspective. We will see that it is this idea of linear perspective that formed the core of Panofsky's argument that we will look at later (Alberti, 1435, p. 196).

Linear perspective is a way of drawing that allows a picture to be depicted accurately with the visual properties of both recession (whereby increasingly distant objects are depicted as increasingly smaller) and the convergence of parallel lines (whereby sets of parallel lines not perpendicular to the viewer's line of sight join together in the distance at what is known as a 'vanishing point') (Figure 8, p. 73). Linear perspective was found to aid the production of pictures that closely resemble their subject matter, and indeed Brunelleschi created a device to prove that his painting of the Baptistery of Florence, which utilised linear perspective, resembled the baptistery closely. Brunelleschi's device involved arranging a mirror that would reflect his painting in such a way that it could be readily compared to the actual scene (Edgerton, 2009, p. 5) (Figure 9, p. 74).

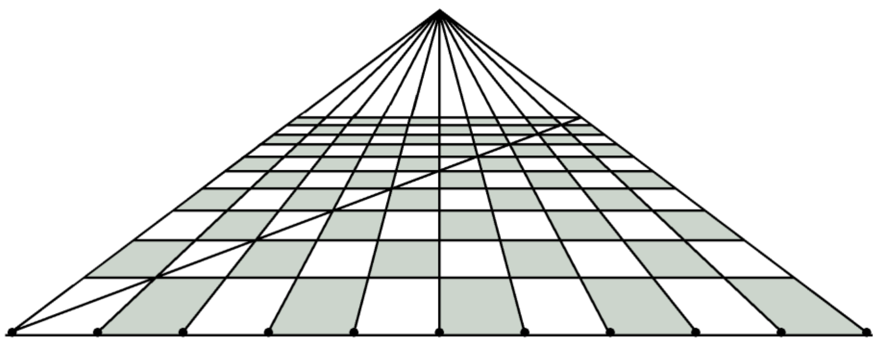

Figure 8 Tiled floor drawn with Alberti's linear perspective method, with construction lines. Diagram by the author.

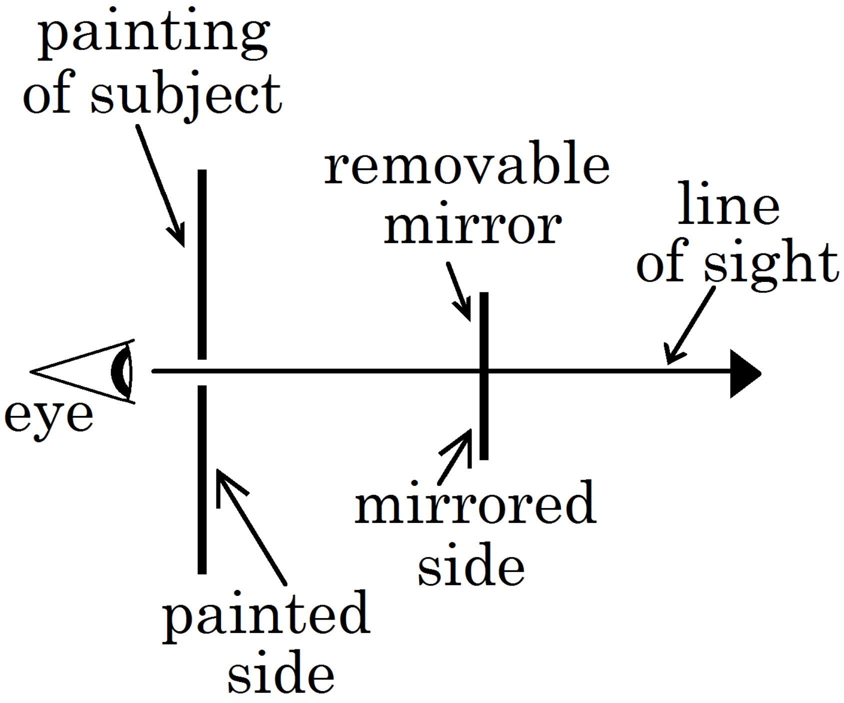

Figure 9 Brunelleschi's apparatus for comparing his painting of the Florentine Baptistery to the actual Baptistery. The line of sight is lined up to finish at the baptistery itself. The image of the painting of the baptistery is reflected on the mirror, which can be seen through a hole in the painting. If the mirror is removed the actual baptistery can be seen, allowing the painting of the baptistery and the real baptistery to be compared. Diagram by the author.

It will now become apparent how linear perspective and the definition of resemblance based on the retinal image come together in conflict. The light reflected from lines in the paving of the plaza and the lines from his painting would travel into Brunelleschi's pupil and onto his retina. This would explain why the painting resembles the plaza, because the retina would be stimulated by the same array of light sent by the plaza and the painting. Panofsky pointed out the clanger in this argument. Linear perspective is created from straight lines but the retina, being a part of the eye, is curved. From this we can deduce that the straight lines of both the plaza and the painting would appear to the viewer as curved, which means we will see the world in a curvilinearly distorted way. We will see that an understanding of the workings of the eye and visual system will provide an understanding to this problem.

Resemblance might be thought of as a more precise term than realism for our purposes here, but again the situation is not quite that simple. Also, depiction in general is the focus of this thesis, rather than realism. However, much of the debate about depiction has involved the study of realism, and hence we might want to examine realism again in more depth before moving on to look at Panofsky's arguments. Newall notes that, broadly, there are three current theories of realism: informativeness, habituation, and verity theories (Newall, 2014, p. 227).

Informativeness theories argue that realism is related to the quality and amount of information a picture provides about its subject. Dominic Lopes, one of the main proponents of the theory of pictorial informativeness, notes two features of a simple theory of informativeness, from which he develops his more complex theory. The first feature Lopes notes about such theories is the idea that the more information a picture has the more realistic it is; the more detail about colour, about shadow, in general how a more meticulous presentation makes for a greater realism. The second feature Lopes notes is the notion of accuracy, namely that the more closely an image copies reality the more realistic it will be (Lopes, 1995, p. 278).

Out of this Lopes develops a more complicated theory of realism via informativeness, based on his theory of depiction that we will look at in *Chapter 2*. In this thesis I will argue for the importance of both resemblance and informativeness theories. We might be tempted to assume without question that resemblance and informativeness theories cleave together rather nicely. However, many writers, including notably Lopes, oppose resemblance theories. Lopes says:

> Let me reiterate that this is not to deny that pictures are experienced as in some sense like their subjects. My position is nicely expressed in Max Black's assessment of the resemblance theory as, 'uninformative, offering a trivial verbal substitution in place of insight. … The objection to saying that some paintings resemble their subjects is not that they don't, but rather that so little has been said when only this has been said.'

(Black, 1972, p. 36), quoted in (Lopes, 2004, p. 35)

We might examine this further by imagining that we are viewing a white square object in a black room. The light reflected from the object enters the eye, where it stimulates an array of cells in the retina. The cells stimulated by the white light will be in a square shape, thus (a) resembling the shape of the object, and (b) providing the visual system with the information that the object being viewed is square. Imagine a painting of this scene, made up of a square painted in titanium white on a background painted in black iron oxide. This painting might be said to be realistic in that it (a) resembles the shape (and indeed the colour) of the object, and (b) provides the visual system with the information that the object being depicted is square.

Consider, however, this comment by Nelson Goodman:

> Consider a realistic picture, painted in ordinary perspective and normal color, and a second picture just like the first except that the perspective is reversed and each color is replaced by its complementary. The second picture, appropriately interpreted, yields exactly the same information as the first.

(Goodman, 1968, p. 35)

Such a ‘negative’ picture cannot be said to resemble the object. Yet if we accept that a picture is realistic if it either contains a lot of information, or relevant information, a ‘negative’ picture is just as realistic as its positive counterpart that scores highly on the resemblance scale. Informativeness, then, does not appear *prima facie* to need resemblance. Before examining Goodman’s argument on this issue further, however, it might be worth to examine first Goodman’s theory of realism, namely habituation.

Habituation deviates from resemblance theory the most. In later chapters, we will examine Goodman’s ideas in greater depth, but we will outline some pertinent ideas here. Goodman argued that pictures do not resemble reality, but are instead symbol systems, with the symbols being in the arbitrary Peircian sense that we saw earlier. He wrote:

> The plain fact is that a picture, to represent an object, must be a symbol for it, stand for it, refer to it; and that no degree of resemblance is sufficient to establish the requisite relationship for reference; almost anything can stand for anything else.

(Goodman, 1968, p. 5)

His argument for what constitutes realism concerns the fact that any symbol system is familiar to its users. We all know our first language intimately, so we consider it natural. Goodman argues that:

> Representational customs, which govern realism, also tend to generate resemblance. That a picture looks like nature often means only that it looks the way nature is usually painted.

(Goodman, 1968, p. 39)

Dominic Lopes hits back at this argument with the notion of ‘revelatory realism’. He argues that if realism involves a pre-existing set of rules becoming so ingrained as to appear 'natural', how can a painting made with a new style appear stunningly realistic on first viewing? An English speaker, hearing French for the first time, would not hear French as natural, but instead as a jumble of incomprehensible sounds. Lopes writes:

> For example, contemporary viewers of Giotto's frescoes expressed astonishment at his accomplishments, praising his pictures as perfect representations of the world. Since Giotto's technique was by no means familiar to them, its realism was of the revelatory variety. Other pictures in initially unfamiliar systems whose revelatory realism nevertheless impressed their early viewers include the first photographs and the color experiments of Constable and the impressionists. As these examples suggest, revelatory realism is no marginal phenomenon: perhaps every system now familiar and so unrevealing was once unfamiliar and its adoption a revelation.

(Lopes, 1995, p. 280)

If Goodman was right, then Giotto's paintings would be a new 'language', and should be incomprehensible to viewers, as English would be to a Brazilian who only ever spoke Portuguese.

We might think, then, that habituation has been dismissed, but we will see that Lopes in fact incorporates parts of Goodman's ideas into his theory. Also, Goodman's ideas have had a partial resurrection in the form of what might be called **verity** theory, developed by John Kulvicki (Kulvicki, 2006). Kulvicki's idea is similar to the idea of informativeness, but he adds to it the idea of 'intra-systemic' depiction. He writes:

> In brief, a picture is realistic to the extent that it depicts its object as having properties that we conceive of such objects as having.

(Kulvicki, 2006, p. 343)

In this, Kulvicki follows resemblance theory in that a picture shares properties of an object, but makes a specific comment about those properties, namely that those features are of a set of features that are fundamental to that culture's perceptions. In this, Kulvicki brings in the notion of language, but in a way that does not require the belief that pictures are symbolic and cannot resemble their subject matter.

This seems like a neat solution, bringing informativeness and habituation together, but we are still left with the problem of revelatory realism. Kulvicki argues that each innovation in art produces a revelation, which changes the standards by which realism is judged. As we will see later, Giotto brought in volumetric form, but not linear perspective. Hence in the realism system of the very early Renaissance, Giotto holds up well, but when linear perspective is added to the 'language', Giotto seems to fail.

Kulvicki's theory may or may not be convincing. It essentially proposes that an artist has a sort of 'palette' of visual features to choose from, which can be added to or removed as the 'language' changes. This provides a neat explanation of realism and changes in realism: the more of the palette you use, the more realistic a painting is, but the palette changes over time, so realism changes. However, one could just as well argue that elements of depiction can simply be added to increase realism, without having to use the idea of each culture or time period having its own set of elements that make up a realistic image.

One argument Kulvicki's theory has that is particularly compelling, however, is how it deals with non-realistic elements. Kulvicki's theory allows for non-realistic elements, such as Giotto's poor perspective, to be a problem in one system (e.g. the world after the advent of photography) but not in another (e.g. Giotto's world). Kulvicki's theory suggests these elements are permissible, and thus accounts for them, while theories of informativeness do not comment on them. Informativeness does not, for example, explain why Giotto's viewers could ignore his undeveloped linear perspective.

In this thesis I will not be developing the notion of realism, but the above discussion is of interest because we can draw from it ideas that will be of interest not in developing a theory of realism, but an overall theory of depiction. It is from the idea of resemblance that we note that pictures share visual properties with their depicted objects. However, pictures clearly deviate from the objects they resemble. Even the most lifelike painting of a horse does not make us stand out of the way to let the horse trot by, and most pictures, such as line drawings, deviate from a full resemblance in many ways.[1] This necessitates bringing in ideas such as informativeness, to explain how artists choose which elements of an object to depict and which to leave out, something we will return to in *Chapter 2* (p. 161). We will also see that notions of informativeness are of interest in explaining how pictures can distort the visual elements of objects, as in Picasso's *Les Demoiselles d'Avignon*.

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[1] We should note, though, the existence of some exceptional tromp l'oeil paintings, such as the Chatsworth House Violin, and the possibly legendary story of the audience running out in terror to escape being run over by the train in the debut of Auguste and Louis Lumière's 1895 film *L'Arrivée D'Un Train en Gare de La Ciotat* (*The Arrival of a Train at La Ciotat Station*).

AGAINST SIMPLE RESEMBLANCE: SACCADES, SCREEN COLOURS, SCREEN RESOLUTION, AND THE CORNSWEET ILLUSION (APPLICATION OF PSYCHOLOGY TO ART 1)

PROBLEMS WITH SIMPLE RESEMBLANCE

We have seen that the idea of the retinal image causes issues, because we see straight lines and yet the retina is curved. This is, however, not the only problem that arises when considering simple ideas of resemblance.

The second problem we will examine can be seen by considering Figure 10 (p. 81):

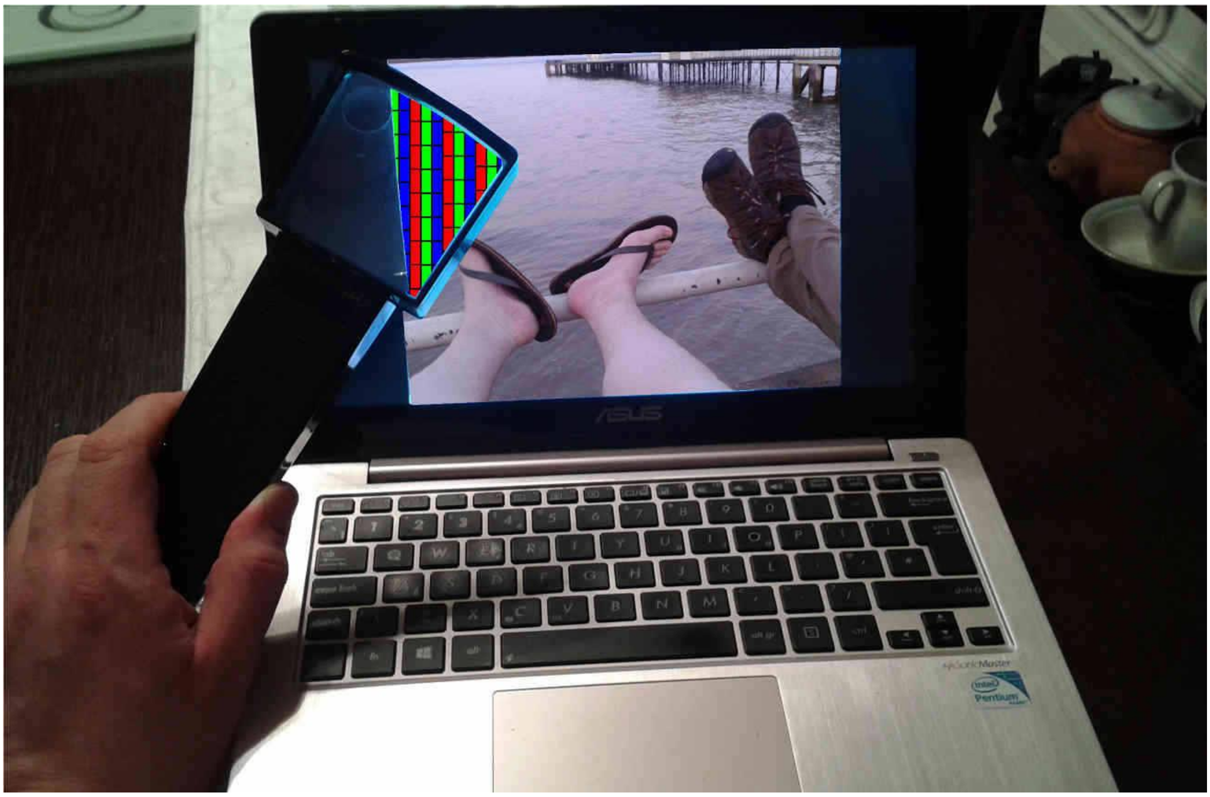

Figure 10 Photo demonstrating the mosaic of pixels that make up a computer monitor. Photograph by the author.

On first glance a photograph on a computer monitor certainly seems to fit our description of resemblance. The magnifying glass shows that in fact it does not. In real life there would be a vast number of colours reflected by the subject. As we see, however, from the figure on a computer monitor there are only three colours, each with varying brightnesses.

The third problem follows on from this. The array of light that reaches our eyes is made up of waves/vast numbers of photons not a mosaic of coloured rectangles. Even if we neglect the problem of there only being three colours of rectangles, we are still left with the problem of how it is that we 'see' a sea-side scene on the computer monitor when we take away the magnifying glass, rather than an arrangement of coloured rectangles.

The fourth problem we will consider can be seen by considering Figure 11 (p. 82):

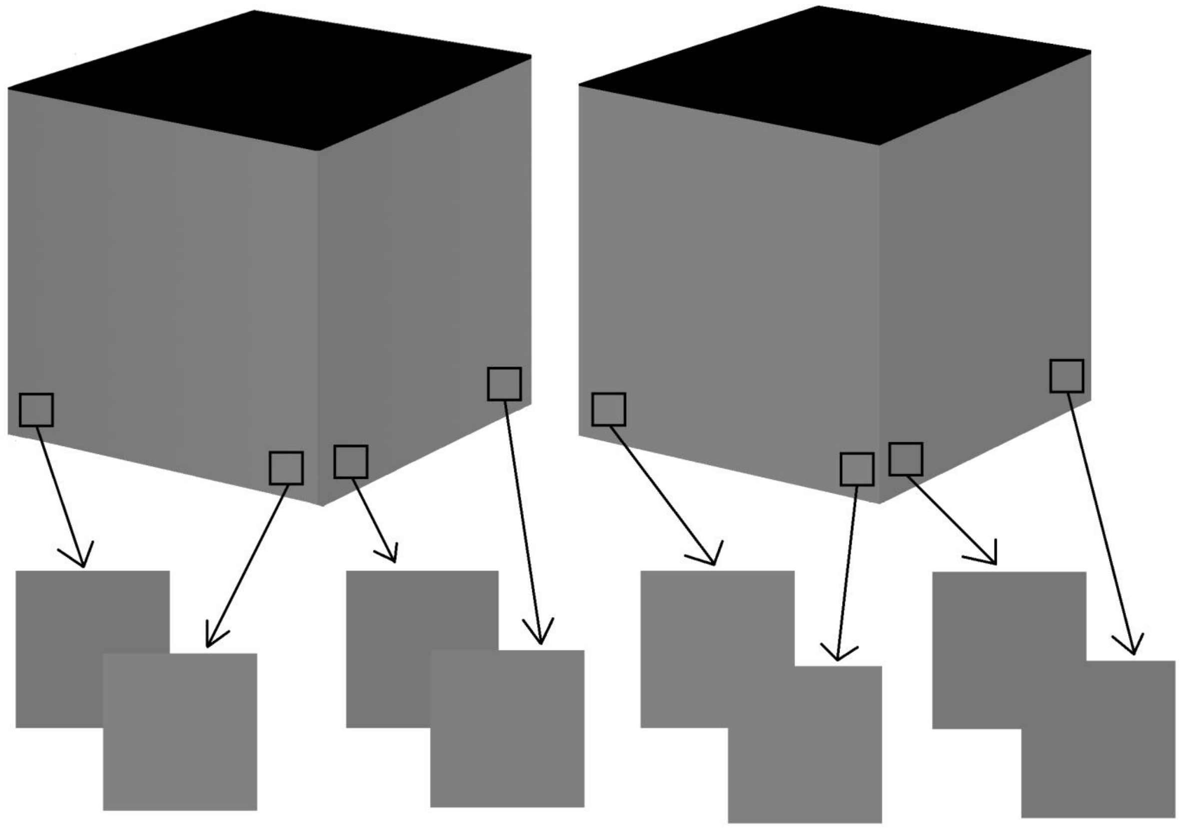

Figure 11 Cubes incorporating the Cornsweet illusion. Both cubes look the same, but the comparisons of colours below show that the left cube involves gradiated colours absent in the right cube. Diagram by the author.

The two cubes look identical, and yet the sides of the cube on the left are gradiated, while the cube on the right has uniformly shaded sides. How can we be deceived that the light coming from a picture is the same as that which would emanate from the subject matter itself? To answer this question we need to examine the workings of the human visual system in depth, and thus we will now present an overview of the human visual system, which will answer the above questions and lay the groundwork for the rest of the thesis.

In this section we will see that the understanding of the visual system developed in the section 'The Visual System' of the *Introduction* (p. 49) will allow us to answer the questions raised by these problems.

APPLYING THE KNOWLEDGE OF THE VISUAL SYSTEM TO PICTURES

Firstly, then, we will examine the issue raised by our knowledge of the curvature of the retina: namely that if we 'see' the retinal image, and the retina is curved, then we surely must 'see' in a curvilinear way. This idea was most notably taken up by Panofsky in his 1925 book *Perspective as Symbolic Form*, in which Panofsky utilised the physiology developed by mathematician Hermann Guido Hauck (1845–1905) argued that the very physiology of the eye distorts the way we see the world (Panofsky, 1925, pp. 32, 78).

Panofsky argued that for pictures that use linear perspective to correspond to the natural way that humans view the world, the retina, and thus the retinal image, would have to be flat like a photographic plate. He thus concluded that the natural way of viewing the world for a human is curvilinear, as approximated by the bottom left picture in Figure 12 (p. 84),

and that paintings that use linear perspective do not appear to us as we naturally view the world. As Panofsky put it:

> The orthogonals of a building which in normal perspectival construction appear straight, would, if they were to correspond to the factual retinal image, have to be drawn as curves. Strictly speaking, even the verticals would have to submit to some bending
>
> (Panofsky, 1925, p. 33)

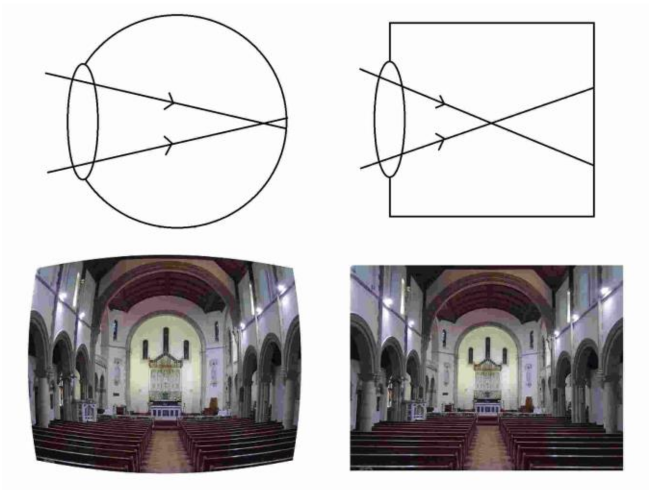

Figure 12 Top: Diagram of eye (left) and camera (right), showing how the light enters the eye/camera, is focused by the lens, and is detected by the retina/film. Bottom: Simulation of image recorded by eye and film. Diagram and photographs by the author.

This argument has been roundly rebutted on many occasions (e.g. (Edgerton, 1975, p. 155) (Elkins, 1996, pp. 195–196, 319) (Pirenne, 1970, pp. 60–61) (Podro, 1982, p. 187)), but these rebuttals have never quite addressed the issue of whether or not the world actually appears to us curvilinearly. An understanding of physiology from the section 'The Visual System' of the *Introduction* (p. 49) will give us the tools to understand this.

Firstly, consider the following argument. Let us imagine someone in the ancient world visits a Greek temple (top image of Figure 13, p. 86). The way the temple would appear to the viewer at first would be the middle image of Figure 13 (p. 86). We note that, as in Hauck's arguments, in this image the temple appears curvilinear. This curvature would be especially notable in the end columns.

Now let us turn to the observation we saw in the *Introduction*. However, experiments have shown that the eye moves around three times per second (Rose & Dobson, 1985, p. 62). Thus, hardly a third of a second after looking, the building is seen from a slightly different view, and appears as, say, the bottom image of Figure 13 (p. 86). The viewer would note that from this angle, the temple would still appear distorted, but in a different way. Most notably the right-hand column would now appear almost straight. Such rapid movements of the eye would provide the viewer with a great number of different viewpoints of the same object. In no two images would any particular element of the building, be it columns, cornice, steps, etc., have the same curvature. For example, the right-hand column is curved in the first image on the retina (the middle image of the diagram); then in the second image, a third of a second later, it is straight (the bottom image of the diagram). As a result, for our visual system to make sense of the images it receives, it would have to be aware that the distortions are due to the curvilinearity of the retina. If it did not, every third of a second or so the building would appear to have different curvatures, thus would appear to wobble like a jelly.

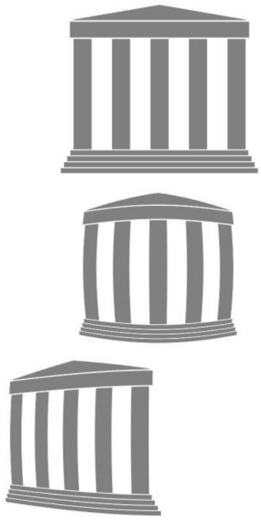

Figure 13 Diagram simulating variations in optical distortion. Top: Undistorted image. Middle: Distorted image. Bottom: Distorted image with different centre. Diagram by the author.

Secondly, there is the issue of the three colours of monitor dots. This can be solved by noting that the visual system has three 'cone' cells, which colour television and printing has exploited to allow for colour reproduction.

Thirdly, there is the issue of resolution. This can be solved by noting that due to the size of the receptive fields in the eye it is not the case that each photon that enters the eye triggers an individual nerve, but instead there is an aggregating process, allowing television and printing to be done at lower levels of resolution.

Fourthly, there is the issue of the Cornsweet illusion. The outline of the workings of the visual system we saw in the *Introduction* shows that the first way that the visual system processes the signals from the eye is to detect edges. The centre-surround cells we saw are fundamental to our perception of the world. Another example of this can be seen in the optical illusion in Figure 14 (p. 87). The large rectangle is made up of two identical smaller rectangles. The smaller rectangles appear uniform in tone, but in fact are a smooth progression from dark on the left to light on the right. If you cover up, say, the right rectangle, it is fairly hard to see the variations in tone in the left rectangle. The visual system is, therefore, weak in detecting smooth variations in tone. If we now consider the two small rectangles joined together, we see a marked variation in tone. The visual system is thus able to detect fairly small jumps in tone. This can be seen further if one places a pen or a finger over the jump; suddenly, the marked variation in tone disappears and we see an even tone. We can therefore note that due to the centre-surround cells of the V1 area, the visual system is good at detecting small levels of contrast, but poor in detecting smooth variations in tone. We should note that this phenomenon of the visual system detecting edges rather than smooth transitions occurs for both tone and hue (Livingstone M. , 2002, p. 58). This property of perceiving the edges of objects that allows us to perceive line drawings. The visual system, then, is not very adept at detecting smooth variations in tone, which results in the sides of the differently-lit cubes of Figure 11 (p. 82) looking so similar.

Figure 14 The Cornsweet illusion. Optical illusion demonstrating the visual system's greater ability to detect edges of tonal contrast than smooth variations in tone. Diagram by the author.

RAMIFICATIONS FOR UNDERSTANDING ART

We can now go on to examine the ramifications this has for our understanding of art. Our earlier idea of figurative art, namely that a picture sends the same array of light through the pupil as would the subject matter itself, can thus be seen to have a problem, namely that images may look the same even though they might send different arrays of light through the pupil as would the subject matter itself.

It is here that we might introduce a quote from philosopher Nelson Goodman. Goodman is mainly noted in art history for his theory of conventionalism, which we will dispute later on. However, he came up with a quote that is of interest here: Goodman says that a picture can be described as

> the Duke of Wellington as he looks to a drunk through a raindrop
>
> (Goodman, 1968, p. 7)

It is worth unpacking this here. Goodman identifies three parts of an image: the Duke of Wellington (the subject in the real world) a drunk (the perceiver) through a raindrop (the effects of distortion of light on the way from the subject to the eye). We might thus say that a picture is in the form of the following:

subject → atmospheric effects → visual system processing

This gives us a useful way of talking about figurative art, by noting that pictures might emphasise different parts of this process. We might thus say that a picture documents the path of light and subsequent nerve signals as they pass from the subject matter (as light), through whatever is in-between the subject matter and the viewer (e.g. air, glass, etc.), and through the visual system (as electrical signals).

This allows us to delineate at least one of the tasks of an artist. An artist records this process, though different artists at different times have emphasised different stages of this process.

The figures in Jan van Eyck's *The Arnolfini Portrait* (1434) are painted clearly, showing the folds of the cloths, and the textures of the wood and metal very precisely. This can be said to be emphasising the light from the subject matter. Claude Monet's *Saint-Lazare Train Station* (1877) shows how light from the station is distorted by the smoke from the trains. This can be said to be emphasising the medium through which the light is travelling. In *Van Gogh's Chair* (1888. London: National Gallery) Vincent van Gogh paints the outlines of the chair thickly, demonstrating van Gogh's (unconscious) detection of edges by his centre-surround cells.

Bringing together these three stages, of light from the subject, of atmosphere, and mental processing, was a major preoccupation of the Post-Impressionists. This was summed up in the work of the Synthetists such as Paul Sérusier (1864–1927) and Paul Gauguin (1848–1903) (Cheetham, 1990). Painter Édouard Vuillard (1868–1940) delineated this process:

> Chardin's still lifes, the white and grey ones, (grapes, pipe) give pleasure through their tonal harmonies and their outline shapes and not by means of the greater or lesser degree of exactitude with which they recall their models which are unknown to us. The difficulty of establishing this firmly in my head after the long hours spent in front of those canvases two years ago imbued with naturalist ideas …

(Vuillard, 1890), quoted in (Thomson, 1988, p. 22)

Vuillard, a 'realist imbued with the aspirations of Symbolism' worked in his paintings to synthesise the different parts of painting, which we saw in the Goodman quote above (Thomson, 1988, p. 7).

We should note here that while this tells us something about art, it only tells us about certain interests. Much of the argument in this thesis, at least up to now, deals with mainly formal concerns. Such concerns have been the project of many artists, such as Cézanne:

> [I will] astonish Paris with an apple.
>
> Paul Cézanne, quoted in (Geffroy, 1922, p. 106)

Another example of this can be seen Maurice Denis:

> 'How do you see those trees?' asked Gauguin; 'If they are yellow, then make them yellow; and that bluish shadow, paint it with pure ultramarine; and those red leaves? Use vermilion.'
>
> (Denis, 1942, p. 42)

We should thus note that our definition of art does not help us address the reasons why Jan van Eyck painted a wedding and why Picasso painted a brothel. What is of interest in this thesis is the contribution to the understanding of art that can be given by examining the visual system, rather than producing a total theory of art.

NON-RESEMBLING DEPICTIONS OF SPACE

If a viewer were to look through Brunelleschi's apparatus at a computer monitor, he or she would probably say that the computer screen resembles the baptistery. However, many pictures, such as Figure 15 (p. 92), are a long way from fooling us that they resemble reality. One of the most obvious deviations from resemblance of Figure 15 is that it makes no attempt to use linear perspective. So if linear perspective does indeed result in resemblance, why might artists avoid it?

Non-use of linear perspective is a very common phenomenon, occurring in non-Western art, and Western art outside of the period between the

Renaissance and Cubism. Given that linear perspective is indeed the most accurate way to depict reality, might we conclude that, say, ancient Egyptian artists painted or Tsimshian Indian artists continue to paint incorrectly, perhaps due to primitive development? Such a conclusion may be readily argued against, without having to resort to the intellectual contortions of Panofsky. Gombrich noted one of the obvious problems with linear perspective, namely that it does not allow the viewer to see around corners (Gombrich, 1960, p. 215). In an ancient Egyptian wall painting, for example, a lake is depicted as if seen from above, but the objects associated are presented as if seen from a different angle: the trees and lake creatures are depicted as if seen from their sides (Figure 15, p. 92). This distortion allows the trees, the creatures, and the lake to each be depicted so as to show the maximum number of visible features of each object. Another example is the drawing we saw earlier by the Tsimshian Indians of the Pacific Northwest (Figure 16, p. 92). In this painting, a bear might be depicted as if flattened out, thus allowing the viewer to see the creature from all sides at once. We can thus conclude that there are a number of ways of depicting objects in space, and that linear perspective is the way that best depicts how we see an object at any given moment, but that linear perspective is only one way of depicting objects, and is not always the best way for any given purpose. As John Hyman puts it: ‘We can be pluralists about art without being relativists about realism’ (Hyman 2006: 211).

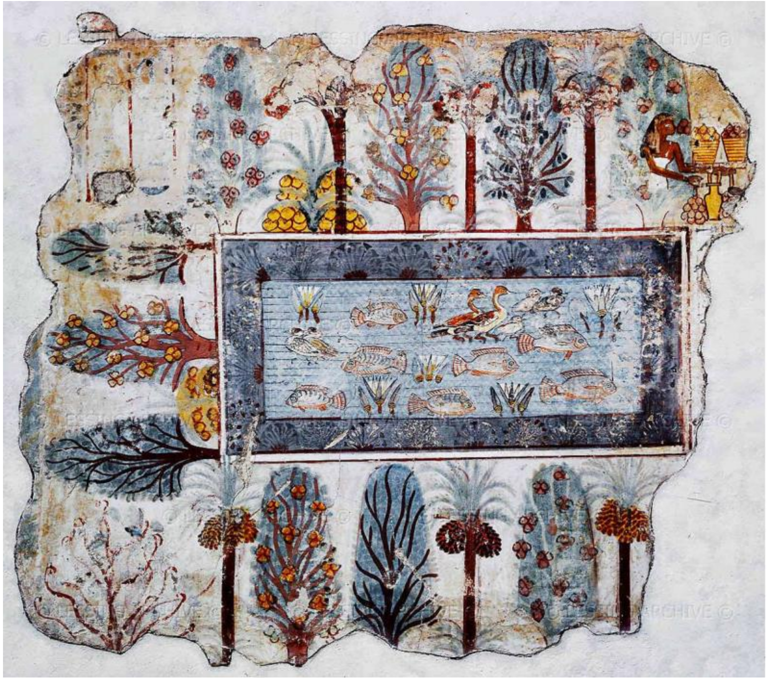

Figure 15 Fragment of a wall painting from the tomb of Nebamun, 18th dynasty, c.1350 BCE.

Figure 16 Flattened picture of a bear by Tsimshian Indians of the Pacific Northwest (Deregowski, 1972).

We might examine this issue in more depth, by looking at a selection of cultures to see how they have depicted objects in space, and seeing what the pros and cons of each approach is. We will begin with Figure 15 (p. 92), the ancient Egyptian wall painting. We see that the artist twisted objects, and parts of objects such as the eyes and legs of figures, so that they present the most informative aspect to the viewer. The viewer would be left with the not difficult task of mentally reconfiguring the objects' spatial relationships in his or her mind. We look down on the scene from above, and yet the water fowl, fishes, trees and the human figure are seen from the side, meaning that the viewer must use his or her imagination to understand the spatial relationships between the objects. We might note that this method of depiction has certain advantages: each object has the maximum number of its features depicted, hence making the image more informative.

If we now look at Figure 17 (p. 94), a thirteenth century Japanese painting, we see that the artist has used a technique more 'realistic' than the Egyptian painting. The objects represented are not twisted artificially to show their most important features to the viewer. For example, the porticos to the left hand side would obscure objects behind them, whereas the trees in the Egyptian painting would not cause this problem. Though inferior to the Egyptian painting in this respect, by sacrificing some of the ability of the artist to depict objects in their entirety, this more realistic method is superior in the respect that it readily displays the spatial relationships of the objects, which is notably of use in displaying the action between the figures on the right.

Figure 17 Illustrated Tale of the Heiji Civil War: Scroll of the Imperial Visit to Rokuhara. Kamakura period/13th century, colour on paper, Tokyo: Tokyo National Museum.

The Japanese picture, though resembling reality more than the Egyptian, still leaves out an important aspect of resemblance, that of recession of space. The figures in the foreground of the Japanese picture are the same size as the figures in the middleground due to the axonometric projection. In Figure 18 (p. 95), *The Hay Wain*, Constable went a step beyond the Japanese picture by using recession. Notably, he not only made the distant trees smaller than those nearer the foreground, but he also made the distant clouds smaller, and thus created a sky that appears to arch over the earth. In achieving this greater resemblance, though, Constable lost another aspect of the scene that was still available to the Japanese artist. Compared to the Egyptian artist, the Japanese artist was not able to represent objects in their most descriptive viewpoint, but by avoiding recession was still able to represent objects in detail even if they were in the distance. Constable, in going even further with realism, not only cannot depict any trees that might happen to be on the viewer's side of the stream due to any such trees occluding the entire scene, but also is unable to depict the trees in the distance in detail.

We might then note that there is a trade-off between resemblance and its alternatives: each step we take towards resemblance offers benefits, for instance the depiction of the interactions between the Japanese figures and Constable's canopy of the sky, but also loses other depictive powers, for example the informativeness of Egyptian painting and the ability of thirteenth century Japanese artists to depict in detail objects in the distance. We will examine these points in more detail in later chapters, as well as examining how it is possible to produce pictures with distortions that the viewer can still recognise.

Figure 18 John Constable. *The Hay Wain.* 1821. Oil on canvas, 130 cm × 185 cm, London: National Gallery.

CONCLUSION

Firstly, we have seen in the discussion of saccades, screen colours, screen resolution, and the Cornsweet illusion that an understanding of the visual system helps us to understand the properties of pictures. We have also seen with the screen colours, screen resolution, and the Cornsweet illusion that due to the properties of our visual system pictures can, in some respects, deviate from a resemblance of a subject matter.

We also saw, however, that Panofsky's idea of the curvature of the retina distorting the appearance of the world is untenable, so in this respect the visual system cannot be said to distort our perception of the world. Furthermore, the argument against Panofsky's thesis leads us to dismiss not only the idea of the retinal curvature distorting our vision, but also the idea of the mind as a viewer of the retina. If there was a homunculus that views the image on the retina as one would a television screen, it would see an image that changes every 0.33 seconds, far more rapidly than even the most frenetic pop video. Therefore, the process of vision must involve the brain and the retina being more closely intertwined.

Secondly, we saw that humans are capable of depicting space in a number of ways, and that these ways do not have to resemble reality in every respect. We saw by the fragment of a wall painting from the tomb of Nebamun (Figure 15, p. 92), and the scroll of the imperial visit to Rokuhara (Figure 17, p. 94), that pictures can depict successfully even when deviating from resemblance. We will examine the psychological mechanisms that allow this to be possible later on. For the moment, we will continue with our slightly more narrow definitions of art. While still lacking a number of features, we have seen our understanding of depiction develop into the (still incomplete) idea that a picture sends the same array of light through the pupil as would the subject matter itself.

Thirdly, we might note some other points Panofsky's arguments raise. The idea of the homunculus is an important one, for its rejection shows that the visual apparatus, i.e. the eye, its muscles, and the processing centres of the brain, are integrated. The eye moves constantly, and yet we do not perceive the world wobbling; our perceptions of the world are fluid and stable. It is the integration of the elements of the visual system that we must examine next.

DISTORTION BEYOND THE PRIMARY VISUAL SYSTEM: THE MULTIPLE SPOTLIGHTS THEORY OF ATTENTION (APPLICATION OF PSYCHOLOGY TO ART 2)

MULTIPLE SPOTLIGHTS

In the section 'Against Simple Resemblance: Saccades, Screen Colours, Screen Resolution, and the Cornsweet Illusion (Application of Psychology to Art 1)' (p. 81) we saw that despite being curved the retina does not distort our perception of the world. Nevertheless, examples such as the Cornsweet illusion from same section will make us wonder if other parts of the visual system do in fact distort our perception of the world.

In order to do this we will examine the way an inconsistent depiction of space might be misrecognised as consistent. We will investigate the differences in the depictions of space between 'The Slaughter of the Innocents' from the *Maestà* altarpiece by Duccio (c.1260–c.1319) (Figure 19, p. 98), which will be our inconsistent example, and *The Marriage of the Virgin* by Raphael (1483–1520), which will be our consistent example. I have chosen these two paintings because of their very different approaches to the depiction of space, despite similarities in the aims of both paintings. Both pictures tell stories: the Duccio, that of Herod ordering the death of the Israelite children; the Raphael, that of the events of the Virgin's marriage. Both paintings contain many details intended by the artists to be focused on by the viewer: the Duccio has Herod performing the order, the killing itself, the grieving mothers, and other details; the Raphael has the placing of the ring on the Virgin's finger, and a variety of activities by the assembled guests. The Raphael, though, has a distinctive feature of its own: its top half is devoted largely to a virtuoso display of architectural space in linear perspective, something that contrasts with the Duccio, which focuses only on the story. Furthermore, the space in the Duccio is inconsistent; as with many of his paintings it contains impossible constructions, such as figures at once standing behind and in front of structures. In order to investigate the reasons for these differences, I will firstly delineate carefully the inconsistencies in the Duccio, apply the theory of multiple spotlights, examine the history of the development of linear perspective, and finally show how the theory of multiple spotlights can illuminate further our understanding of history.

Figure 19 Duccio. 'Slaughter of the Innocents', fragment of the *Maestà* Altarpiece. 1308–1311.

I will begin, then, with an analysis of the space in Duccio's 'The Slaughter of the Innocents'. The painting contains three groups of figures: those involved with the execution of the massacre (let us call them the Front Group), Herod and the two figures either side of him (the Herod Group), and the two guards to the left of the Herod Group (the Guard Group). The Front Group and the Herod Group together are the main definers of the painting's space. They define the space fairly coherently: the Herod Group is clearly at the back, the Front Group is clearly in the foreground, and the two groups are separated by a plane that can be traced from the wall at its lower edge, going through columns as we follow the plane upward, with a cornice delineating its top. (I will refer to this plane as the Dividing Plane.)

The inconsistency in this space occurs with the interaction between the Guard Group and the Dividing Plane. The heads of the guards are positioned in front of the edge of the wall on the left of the picture. If we follow this wall-edge up it meets the cornice, so we must assume that the guards are in front of the Dividing Plane. However, the guard wearing green is situated behind one of the figures in the Herod Group, so we must assume that the guards are behind the Dividing Plane: a clear spatial contradiction.

These sorts of spatial contradictions were common for Duccio and his contemporaries. For example, in *The Deposition* by Sienese artist Ugolino di Nerio (c.1280–1349. London: National Gallery) the Virgin stands behind the base of the cross, yet holds the face of Jesus who is in front of it. Another example can be seen in *The Vision of the Blessed Clare of Rimini* (c.1333–1340. London: National Gallery) by Giovanni Francesco da Rimini (died 1348), where the arms of the figure on the extreme right are in front of the Crucified and Risen Christ, and yet the figure stands behind Christ.

Duccio often creates quite extreme spatial contradictions; other examples from the *Maestà* include 'St. Peter First Denying Jesus' where the woman on the left stands well in front of St. Peter, yet holds a handrail behind him, and 'The Parting from the Apostles', a quite audacious example where the doorway on the left is depicted behind the figure group on its left side and in front of the figure group on its right side, the reason seemingly being to use the right-hand pillar of the doorway as a device to divide the composition. The twentieth century Dutch artist Maurits Cornelis Escher (1898–1972) made numerous prints exploring the imaginative possibilities of spatial contradictions, such as his 1961 *Waterfall*, which depicts water falling downwards indefinitely. Mathematician Roger Penrose (born 1931) popularised the Penrose Triangle as the quintessential example of such figures (Figure 20, p. 100), in which each vertex of the triangle on its own depicts a consistent three-dimensional structure, yet the figure is spatially inconsistent when looked at as a whole.

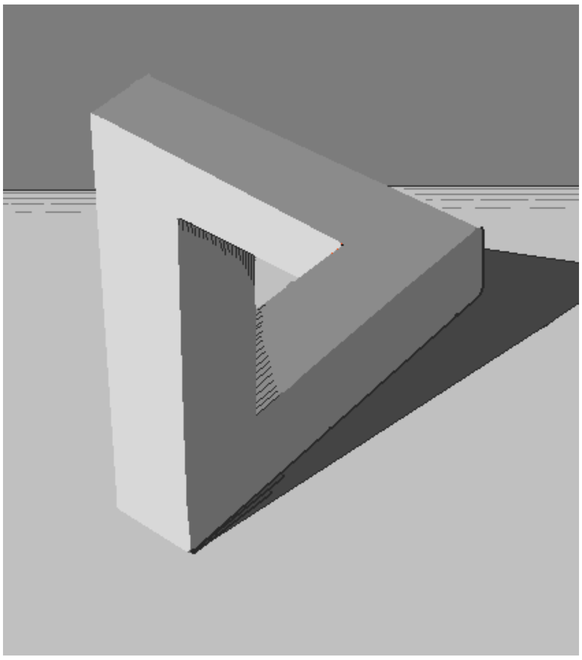

Figure 20 Penrose Triangle. Diagram by the author.

This sort of inconsistency would largely disappear from art as the Renaissance progressed. Hogarth would lampoon such contradictions in his 1754 engraving *Satire on False Perspective*. Space would tend to be depicted coherently in paintings, as in, for example, Raphael's *The Marriage of the Virgin*.

Having identified the problem that we are able to recognise spatial depiction despite inconsistencies, we can now both argue for a solution, namely the experimental psychological theory of multiple spotlights, and situate this theory in history. The link between cognitive psychology and historical analysis in my examination is the constant movement of the eye.

What is important about the constant movement of our eyes is that it indicates that the focus of our attention is constantly changing. It is this notion of attention that is of relevance here. Recent research has resulted in what is known as the 'multiple spotlights' theory of attention.

Before examining this theory, it will be worth briefly examining the notion of attention. Attention is often thought of as being a totally conscious process; for example, if I no longer want to watch the television I will stop looking at it and instead move my gaze to a book or my smartphone. While attention is indeed partly conscious, there are attentional processes that are unconscious, notably many of those concerned with spatial discrimination. We should keep this in mind when considering theories of attention (Kentridge, Heywooda, & Weiskrantz, 2004).

The multiple spotlights theory posits that attention can be divided between different spatial areas of a visual stimulus. Experiments have demonstrated that this theory is superior in explaining attentional phenomena than alternative theories, which include the 'single spotlight' theory, which posits that attention occurs in a *single* small area, and the 'zoom-lens' theory, which posits that attention is like a camera's zoom-lens: zooming out to a wider view, zooming in again to a tighter view, and then zooming out again to a wider view (Awh & Pashler, 2000) (McMains & Somers, 2004) (McMains & Somers, 2005) (Morawetz, Holz, Baudewig, Treue, & Dechent, 2007).

The main feature of the multiple spotlights theory is that attention is localised in a number of small areas, between which attention rapidly darts, and that we give little or no attention to the space between these areas. Hence when viewing a painting, our attention moves rapidly between these localised areas of the picture surface, but we ignore the areas in-between. This view contrasts with the single spotlight theory, which would argue that the eye focuses on a single small area of a painting at a given time, and the zoom-lens theory, which would argue that we view the whole of a given painting, zoom in an area that interest us, and zoom out when we lose interest in that detail. Furthermore, experiments have shown that we can only give a relatively small amount of attention to any particular area of a scene: hence we can give attention to a number of small areas, but if we attempt to give all our attention to fewer larger areas, our attention to each larger area is no more than the attention for a smaller area. This might happen, for example, in driving, when our attention might be given to a number of small areas of the road, and thus miss areas in-between (Figure 21, p. 103).

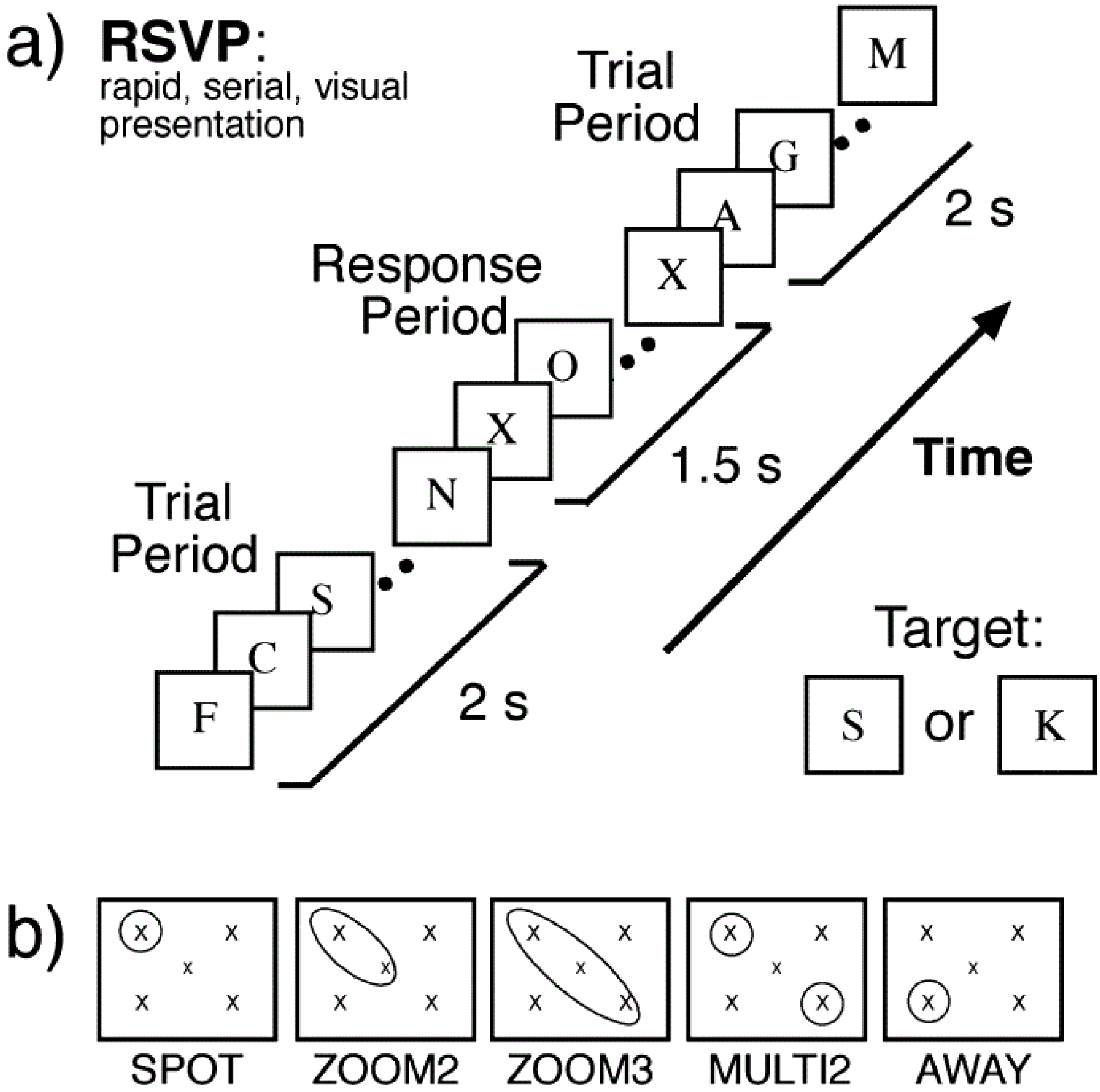

Figure 21 'Visual stimulus configuration. Five RSVP streams were displayed simultaneously. *a,* Subjects fixated the central stream while monitoring attended streams for the appearance of a target letter (S or K) during each 2 s trial period. Each trial included a 1.5 s response period indicated by the appearance of the letters X and 0. *b,* Attentional deployment varied across blocks of trials. To investigate the zoom lens mechanism, attention was deployed to a single peripheral location (SPOT) or to that location plus one or two adjacent locations (ZOOM2 and ZOOM3). To investigate multiple spotlight selection, two disjoint streams were attended (MULT12). As a baseline control measurement, attention was also directed to an otherwise never-attended stream (AWAY).' (McMains & Somers, 2005, p. 9445).

The aspect of history that is related to the movement of the eye is an important facet of Brunelleschi's experiments in optics that we saw in the section 'Resemblance and the Debate about Depiction' of *Chapter 1* (p. 66).

In order to achieve the aim of depicting space realistically an artist would need to exclude certain features of vision in image making. Brunelleschi's experiments to measure success in verisimilitude demonstrate the features of vision that need to be excluded to achieve such an aim. He excluded stereoscopis by simply blocking the vision from one eye, and excluded the movement of the subjects by choosing subjects that are largely still. Another feature of Brunelleschi's apparatus was the narrow viewing hole, and this is what is of importance here: the small viewing hole allowed Brunelleschi to exclude the constant movement of the eye itself (Edgerton, 2009, p. 5) (Figure 22, p. 104).

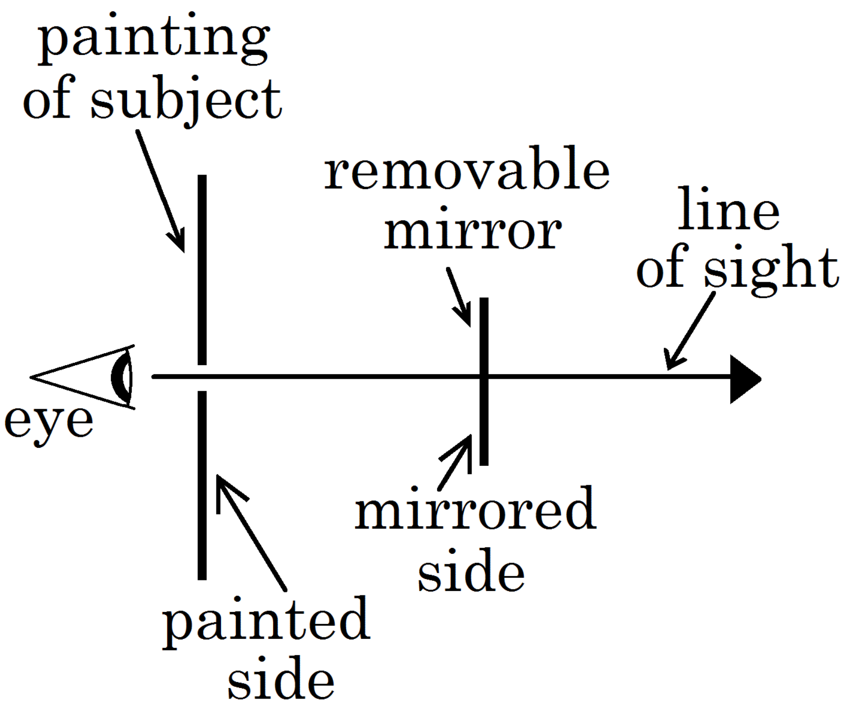

Figure 22 Brunelleschi's apparatus for comparing his painting of the Florentine Baptistery to the actual Baptistery. The line of sight is lined up to finish at the baptistery itself. The image of the painting of the baptistery is reflected on the mirror, which can be seen through a hole in the painting. If the mirror is removed the actual baptistery can be seen, allowing the painting of the baptistery and the real baptistery to be compared. Diagram by the author.

We can now return to Duccio's and Raphael's paintings. From multiple spotlights theory we learn that we cannot give our attention to an entire picture surface and the details of it at the same time. Hence, if we wish to view a picture as a whole and then focus in on details, we must perform two separate actions: first view the picture as a whole, then cease giving our attention to the panel in its entirety, then perform the next task of looking at details. When we look at the whole picture, we cannot see details, as according to the cognitive research cited above we cannot give much attention to this larger area. Also, when looking at details, while we can have many areas of detail 'on the go' at any one time, we cannot see between the separate areas of our attention.

Hence with the Duccio painting, we can, say, look at the whole painting somewhat cursorily, then look at details such as Herod's commands or the dialogue between the guards; and with the Raphael, we can look at the whole picture, again somewhat cursorily, and then look at details such as the presenting of the ring, or the activities of the figures in the background. The difference is that while with both paintings the depiction of space is coherent for each of the details, with the more cursory views of the whole of each image, Duccio makes little attempt to present a coherent depiction of space, while Raphael presents space more or less perfectly. The reason for this can be seen in the difference between the importance that overall space had for the two artists. Duccio was wholly concerned with the narrative of his picture, while Raphael is interested in the depiction of space itself. Duccio intended his viewers to focus in as soon as possible on the details of his picture. It presents a series of events: Herod giving an order on his throne, the finger with which he condemns the children leading us to the weeping mothers in the opposite corner; as our eyes dart around, we see the cruel stabbing of one baby, the somewhat disinterested expression of the face of the guard at the farthest left, perhaps then to dart to the ambiguous expressions of the guards in the corner. At no stage is Duccio really interested in making his audience view the painting spatially as a whole. Hence the spatial ambiguities, such as the guards being both behind Pilate's platform and in front of it, would not have been of concern to Duccio. In contrast, even though Raphael's painting has details to be observed, such as the expression of the face of the minister marrying the couple or the figure on the far left who is looking at the viewer, Raphael is also interested in the depiction of space itself. The upper half of the canvas is largely given over to this interest, the flooring of the square chosen to create this roomy space; we might contrast this to the Duccio, which contains little depiction of the architectural structures and is almost totally covered with detail, barring a small portion of gold in the upper left.

We can thus say that for their overall conception of a painting Duccio and Raphael differ: Raphael used a coherent view of space to organise a painting, and indeed was interested in depicting space itself, while Duccio used a narrative scheme to organise his painting and (in this panel) had little interest in linear perspective. Raphael's interest in the depiction of space can also be seen in the large proportion of the surface area he devotes to architectural space in other paintings, for example *The School of Athens* (1510–1511). Duccio was, of course, one of the most innovative painters of his time, and in other paintings we can see him deviating from his focus on narrative and prefiguring the interest in space by Raphael. For example, in another fragment of the *Maestà* altarpiece, 'Temptation of Christ in the Temple' (1308–1311), we see Duccio compacting the narrative elements into one half of the picture, this time the top, hence leaving the other half to experiment with the depiction of the space of a building with a polygonal plan. As Raphael spent time presenting space and deviating from the narrative elements, so Duccio carefully builds up the space in the interior of the temple, which the viewer takes a peek at through the door on the right (Jannella 1991: 36).

It is not true, though, that in the Herod panel space was unimportant for Duccio. In order to depict the figures Duccio was obliged to take care with space, so for individual details that depict episodes of the narrative, coherent space was important. Hence we can say that Duccio viewed space in a localised way, but later in the Renaissance there was an attempt to view space in absolute terms. Brunelleschi's device was partly for disciplining the eye to see this absolute space, which might not be immediately obvious to the observer.

Why, though, if the perception of absolute space is not necessarily immediately obvious to the viewer, is it possible for artists to create spatially consistent scenes, and more so for viewers to detect spatial inconsistencies? In order to answer this question we might begin by examining the Duccio again, and examining the point that depiction has a very important difference from the real three-dimensional world.

The way that a picture is different from reality that is important to us here is that, for a picture that wishes to 'send the same array of light through the retina as would the subject itself', the picture can only present us with one viewpoint. As we saw earlier, though, the eye is capable of moving several times a second and thus presenting us with many viewpoints. Hence there is something artificial about a picture, namely its fixed nature, and it is with this particular aspect of a picture's artificiality that we have our answer.

The fixed view of a picture allows our visual system to create new groups of multiple spotlights, which is why our visual systems allow us to detect the spatial inconsistencies in in the Duccio; if we are on the lookout for inconsistencies, we can change our spotlights to find spatially inconsistent areas.

It is here that we might be able to resurrect the ideas of Panofsky's that we examined earlier. As we saw, the retina does not distort vision, but as we saw with the Duccio, Escher's drawings, and the Penrose Triangle, the visual system further up in the brain can lead us to accept inconsistent space. It might thus be said that perceived space of pictures might not correspond in this way to real space. This might lead us to reconsider Panofsky's quote from *Perspective as Symbolic Form* using the concept of multiple spotlights rather than the retinal image:

> Perspective, in transforming the ousia (reality) into the phainomenon (appearance), seems to reduce the divine to a mere subject matter for human consciousness; but for that very reason, conversely, it expands human consciousness into a vessel for the divine

(Panofsky, 1925, p. 72)

CONCLUSION

What can we conclude from this about distortion in art and perception? Certainly, artists may consciously distort objects in pictures in a way that results in a picture that does not fully resemble reality, as we saw with the Penrose illusion. We should also, however, note that it is possible for artists to depict in a way that does not fully resemble reality, but that the viewer is not fully aware of, as we saw with the Duccio and the Rossetti. This may be unconscious on the part of the artist, as probably happened with the

Duccio, or more or less conscious, as probably happened with Rossetti. This leads us to the conclusion that perhaps the visual system is not very reliable, a point that we will examine in the next section of this chapter.

THE RELIABILITY OF THE VISUAL SYSTEM: COLOUR VISION (APPLICATION OF PSYCHOLOGY TO ART 3)

INTRODUCTION

In order to argue for the reliability of the visual system I will examine the problem of colour vision and colour in art. This has been an extremely contentious area of discussion, though we will see that the nature of the contention is itself illuminating. We will see that there are two points of view, colour objectivism and colour subjectivism, and we will largely follow John Hyman's argument to reach a solution (Hyman, 2006).

There has been an enormous amount of study into colour vision, and as with other areas of this thesis we will find we can apply these theories to the understanding of art. This particular area has an interesting twist, however. As the psychophysiological basis of colour was being uncovered, artists such as Delacroix and Seurat took an immediate interest, lured both by scientific interest and the promise of brighter colours (Düchting, 1999) (Cochrane, 2014). Many of the theories were used by artists despite being either incompletely formed or misunderstood, thus leading to odd effects in the paintings produced. The use of these incomplete or misunderstood theories is of particular interest in understanding the interaction of science and art. In order to benefit from this understanding, we will first examine the development of the scientific theory of colour, then move on to examine the debates surrounding it.

The complexities involved in the debate about colour will illuminate the issues surrounding depiction, and the visual system in general. We will see how the particular structure of colour vision could lead us to doubt the reliability of the sense of vision, but we will see why in fact the colour system does provide us with a reliable perception of reality. Furthermore, we will see how this affects our understanding of depiction, and importantly we will see how the debates about depiction and visual perception in general and interlinked.

The section is divided into six subsections. ‘Colour Vision—Cones and Rods, What and Where’ (p. 111) presents a preliminary examination of the colour visual system. The visual system is complex, motivating an initial examination of the two different paths of vision. This will provide us with a framework that will let us move on to the topic of this section proper, that of the photoreceptors in the eye that deal with the detection of colour. ‘Colour Vision—Additive and Subtractive Colour Mixing’ (p. 113) examines the various elements of the physiological account of colour vision. ‘Colour Vision—Opponent Process Theory’s Pillarbox Red/Green and Deep Blue/Yellow Channels’ (p. 126) and ‘Colour Vision—Opponent Process Theory’s Brightness Channel’ (p. 132) examine the main competitor to Helmholtz’s theory, and how recently there has been an attempt to combine the two into a single theory. ‘Colour Vision—Munsell’ (p. 140) examines a final important colour theory, the Munsell system, which will be explained in terms of a prominent colourists, Veronese. Finally, ‘The Conflicting Ideologies of Colour’ (p. 146) examines what the above can tell us about the nature of vision and art.

COLOUR VISION—CONES AND RODS, WHAT AND WHERE

We will begin by recapping what we saw earlier about the scientific knowledge about the role of the retina in colour vision and the role in colour vision the two 'paths' visual information take as it is passed from the eye to the brain.

Firstly, there is the physiology of the retina. As we saw earlier, there are two types of light-sensitive cells in the retina: rods, which are monochromatically sensitive and deal mainly with movement and night vision, and cones, which are sensitive to both brightness and colour, and deal with recognition and identification and operate in brighter light. It is a common misconception that rods deal with brightness and cones with colour; in fact both rods and cones detect brightness. The rods, perhaps, evolved mainly for hunting at night. The main requirement for hunting is speed of response; prey often requires little identification except for movement, and time spent on more complex identification would slow down the response of the hunter. The cones, which work best in the day and give excellent identification of colour, perhaps evolved for identifying different types of fruit, which would be picked during the day. It would be important to identify the colour of fruit in order to identify unripe and poisonous specimens (Jacobs, 2009). Generally, artworks do not move and are well-lit; they are thus are more like fruit than prey. As a consequence, in our discussion of painting we will tend to ignore rods and focus on cones, but we will see in the appendix that knowledge of the workings of rods is important in understanding cinema.

Secondly, there are the two 'paths' of information. As we saw earlier, the visual system is rather odd in that the eyes are in the front of the head while the main part of the brain that processes vision is at the back. On the way to the back of the brain electrical signals from the eyes pass through an area of the brain known as the lateral geniculate nucleus (LGN). The LGN can be compared to a relay-station, in that it splits data into three largely independent paths. It is located just beyond the optic chiasma, shown in Figure 23 (p. 113). The two main paths are the magnocellular ('M', or 'where') pathway, which is most sensitive to information about movement, which it gains mostly from the eyes' rod cells; and the parvocellular ('P', or 'what') pathway, which is most sensitive to fine details and colour, which it gains mostly from the eyes' cone cells. We will look in detail at the rod and cone cells later. The third of the pathways is the koniocellular ('K') pathway, which is most sensitive to information from the eyes' blue detecting cone cells. All three of these pathways feed information into the visual cortex area at the back of the brain, where the initial processing of visual information occurs. The first area it feeds into is the primary visual cortex, or V1 area. Due to their dominant role in vision we will focus primarily on the M and P pathways, starting with the P, or 'what', pathway, and in particular how it processes information about colour.

(Blake & Sekuler, 2006) (Clay Reid & Martin Usrey, 2013) (Eysenck & Keane, 2010) (Gazzaniga, Ivry, & Mangun, 2009) (Jacobs, 2009) (Livingstone M. , 2002).

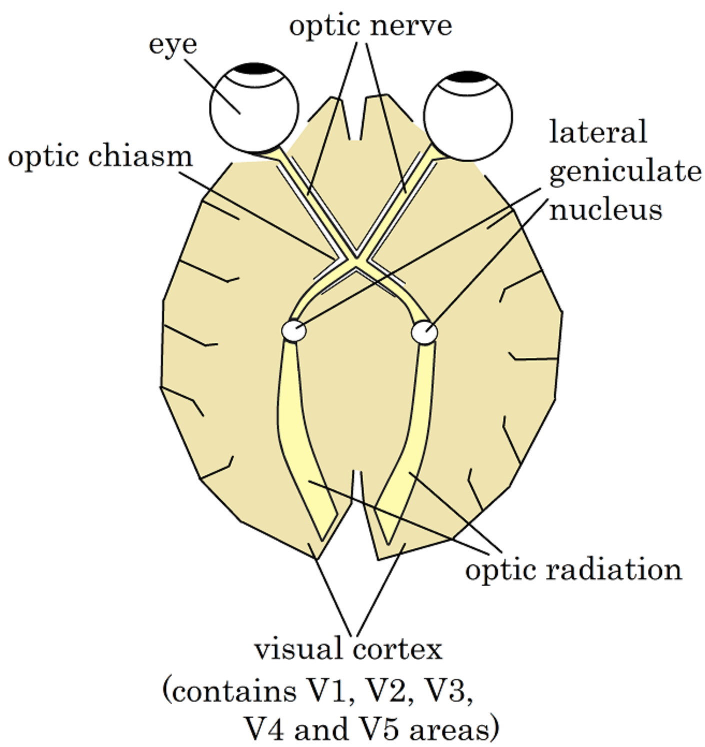

Figure 23 Transverse basal (cross-section from below) view of the human brain, showing the visual system. Diagram by the author.

COLOUR VISION—ADDITIVE AND SUBTRACTIVE COLOUR MIXING

Our current knowledge of colour and colour vision developed over a long period of time. In order to continue with our examination of colour vision we will return to the eighteenth century to see how the psychophysiological basis for colour was discovered. We will see that the pursuit of understanding visual processes was not linear, and furthermore that the adoption of scientific ideas into art was not linear either. There were many, often intense, debates about the properties of vision before the truths of the various components were reached. Further to this, artists would often misunderstand the theories developed by scientists, which we should note were anyway still in a state of development. It is thus illustrative to examine how artists react to these problems, and what effect it had on their work.

> All colours are the friends of their neighbours and the lovers of their opposites.
>
> Marc Chagall

We will begin by examining a number of people who wrote on the subject of colour and light. Firstly, we will examine the writings of scientist Isaac Newton (1643– 1727). Newton was able to show that white light is made up of many different colours. He arranged these colours in a wheel shape, believing this ordering revealed an underlying system in the colours (Figure 24, p. 114). We should note again that it is not necessary to follow Newton's colour names; it is possible to subdivide the wheel in many other ways, some of which we will meet later (Gage, 1993, p. 168) (Newton, 1704).

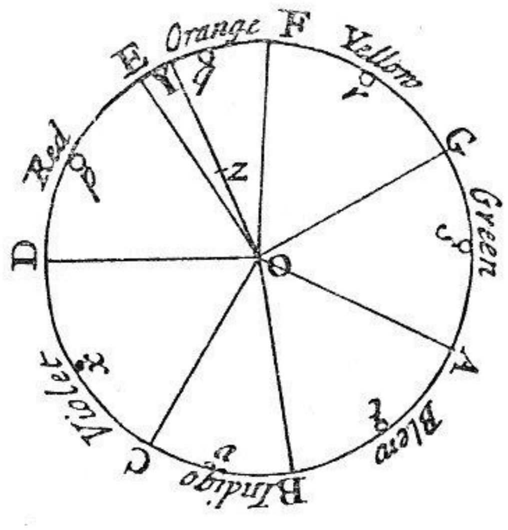

Figure 24 Newton's colour wheel, from his 1704 book *Opticks* (Newton, 1704).

The next major stage in the process of development can be seen in the work of scientist Benjamin Thompson (1753– 1814), who in 1793 coined the term *complementary colours*. Thompson shone a coloured light at an object and looked at its shadow on the wall. He argued that the colour of the shadow was the colour opposite to the colour of the light on the colour wheel. Consider Figure 25 (p. 115). For example, if a light of colour 'a' is shone on a white wall, Thompson argued that the shadow will appear to be colour 'b', and if a light of colour 'c' is shone on a white wall, the shadow will appear to be colour 'd', and if a light of colour 'e' is shone on a white wall, the shadow will appear to be colour 'f'. The diagram shows six pairs of complementary colours in total. Thomson recognised that complementary colours, when placed next to each other, would appear more colourful and vibrant.

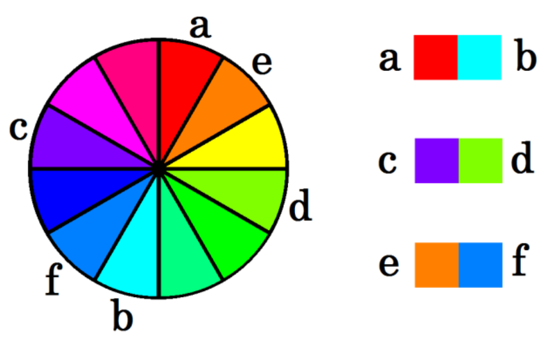

Figure 25 Diagram illustrating complementary colours. Diagram by the author.

Another important discovery was the 1793 finding by scientists Thomas Young (1773–1829) and Helmholtz concerning there being three types of colour detecting cells in the eye. Young's discovery would later become important in understanding the process whereby the colour wheel and complementary colours could be understood. Young discovered that the eye has three types of receptor cells for coloured light. Young found that the three types of receptor are sensitive to pillarbox red, green, and deep blue light, which became the basis for our knowledge of additive colour mixing.

The final writer we shall consider in this early progression of understanding colour is Chevreul, who we met earlier. Chevreul noticed that the contrasting properties of light of two objects or situations often result in the enhancement of the objects' or situations' properties. We might recall that he wrote:

> (8.) IF we look simultaneously upon two stripes of different tones of the same colour, or upon two stripes of the same tone of different colours placed side by side, if the stripes are not too wide, the eye perceives certain modifications which in the first place influence the intensity of colour, and in the second, the optical composition of the two juxtaposed colours respectively.
>
> (Chevreul, 1855, p. 7)

For example, if one walks into a house from the outside on a bright sunny day, on immediately entering the house the hallway will appear very dark. On the other hand, if one enters the same hallway from the kitchen, the hallway may appear fairly well lit, even if the hallway is the same brightness as when one walked into it from the sunny exterior. Another example can be seen in Figure 26 (p. 117). We can see that in each of the three pairs the central squares appear different, despite both the left and right square of each pair being an identical colour. We should note, for example, that the orange square on the top left of Figure 26 (p. 117) appears less red that the one on the top right, despite both squares being the same colour. Chevreul called these phenomena *contrast effects*.

Chevreul identified two types of contrast: successive and simultaneous. Successive contrast occurs when one stimulus is followed by a contrasting stimulus, such as the example above of walking from a sunny day into a dark house. Simultaneous contrast occurs when the stimulus occurs at the same time, and is physically juxtaposed. Figure 26 (p. 117) shows demonstrates three types of simultaneous contrast, that of hue, brightness, and saturation.

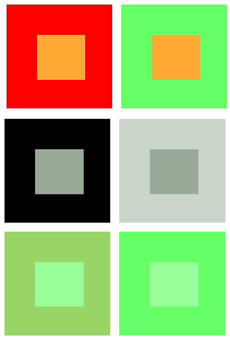

Figure 26 Simultaneous contrast. Top: Hue. (The middle square on the right looks less red than the middle square on the left, despite both middle squares being the same.) Centre: Brightness. (The middle square on the right looks lighter than the middle square on the left, despite both middle squares being the same.) Bottom: Saturation. (The middle square on the right looks more saturated than the middle square on the left, despite both middle squares being the same.) Diagram by the author.

These ideas lay the groundwork for our modern understanding of colour. We might note that Chevreul's ideas would have an influence far beyond tapestry making. We can also see that Chevreul's ideas would be mixed with Thompson's. The artist Delacroix was eager to make his paintings brighter and more colourful, and incorporated Chevreul's discovery of simultaneous contrast and the idea of complementary colours into his work. One of his early applications is the painting *Dante et les esprits des grands hommes* (1841–1845, Paris). Impressionist Pierre-Auguste Renoir (1841–1919) also made use of these ideas in his 1879 painting *The Seine at Asnières*.

The juxtaposition of the orange of the boat and the blue of the water makes the orange of the boat particularly strong, due to simultaneous contrast (Roy, 1985, p. 19). This is demonstrated by Figure 27 (p. 118), where the blue has been replaced with the less contrasting red.

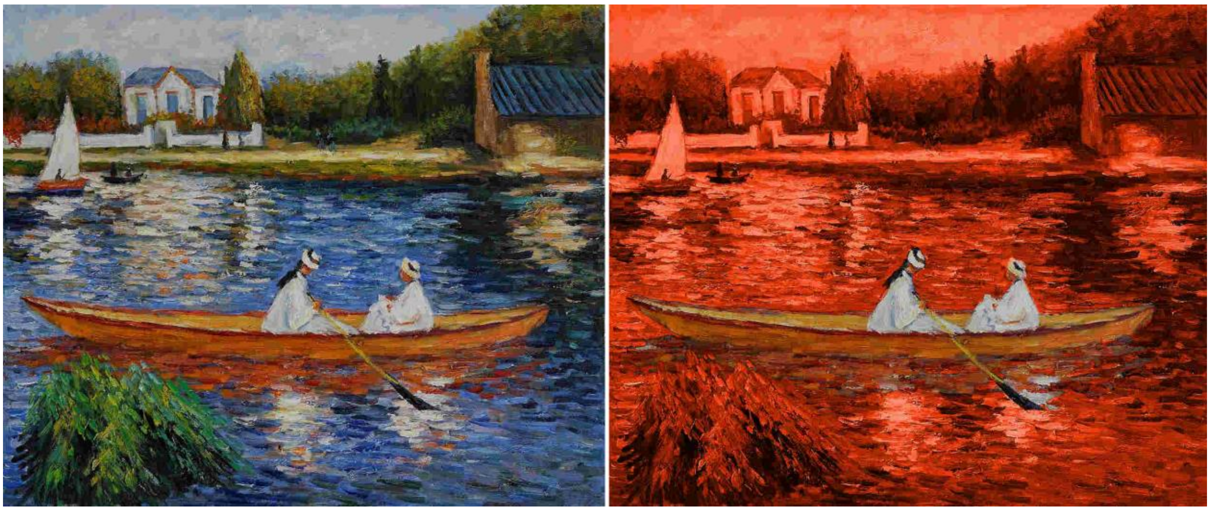

Figure 27 Renoir. *The Seine at Asnières*. 1879. Left: original painting. Right: modified so that river is red-orange, while the boat and its reflection is unchanged. Modifications by the author.

It is notable that Chevreul worked in a tapestry factory, because it is the nature of tapestry that brought about his second discovery. Chevreul observed that when different dyed threads were woven together the colours appear to mix together. Importantly, when threads of two complementary colours were woven together the result was a grey. This notion of colours mixing together in the eye became known as optical mixing, which would become of great importance to the Post-Impressionists (Chevreul, 1855) (Kemp, 1990).

Optical mixing is most famous for having been used in Pointillism, which was developed by Seurat and Signac. Seurat and Signac, however, not only used optical mixing, but also explored simultaneous contrast. Seurat believed that by mixing contrasting colours optically, he would combine the properties of simultaneous contrast and optical mixing to give his colour mixes a vibrant look. We will see in this thesis that Seurat misunderstood some of Chevreul's theories, but that nevertheless Pointillism was able to benefit from scientific ideas. We will also see that discoveries from more recent vision science, namely the theory of visual scales, can explain further properties of Pointillist paintings. (Signac, 1899 (Editied version: 1964; Trans: 2003)) (Phillips J. , 2005) (Cochrane, 2014).

Young identified that the eye has three types of receptor for coloured light, but it was Helmholtz who developed this notion to its highest degree. We should note that colour mixing is not just to do with the properties of the eye, but with the chemical properties of the paint.

Firstly, we will deal with the physiology. As we saw earlier, the colour receptor cells in the retina are called cones. There are three types of these cones, which I have called pillarbox red, green and deep blue, names I am giving to roughly describe the wavelength of light they are most sensitive to. The colours pillarbox red, green and deep blue make up the 'primary' colours, and from these primaries other colours can be formed. Mixing equal amounts of two primary colours makes a secondary colour, for example mixing a pillarbox red light emitting diode with a green light emitting diode produces cyan light. In total, there are three secondary colours: yellow, cyan, and magenta (Figure 28, p. 119).

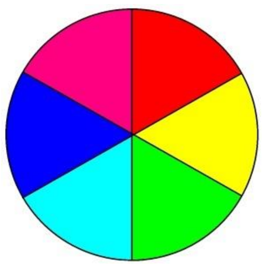

Figure 28 The colour wheel. Diagram by the author.

Secondly, we shall deal with the physical properties of paint and light sources. Paint acts differently to transmitted light sources such as L.E.D.s (Light Emitting Diodes). If we mix pillarbox red and green light we get cyan, but if we mix pillarbox red and green paint, we do not get cyan paint. Paint instead acts like a filter, where one 'subtracts' colour ('subtractive colour mixing') rather than 'adding' colours to each other as with L.E.D.s ('additive colour mixing').

Figure 29 (p. 120) demonstrates in a simplified form how paint filters out colours. Paint is made up of pigment, say cadmium red or terre verte, suspended in a medium, say acrylic emulsion or linseed oil. White light, which contains all the colours of the spectrum, enters the paint layer. Light hits a particle, and is either absorbed by it, or is bounced off. If the light is bounced off the particle it will travel on to either hit another particle, or if its way is clear, it will exit the paint layer. If a retina is in the path of an exited beam of light, it will be seen along with other beams of light from the painting.

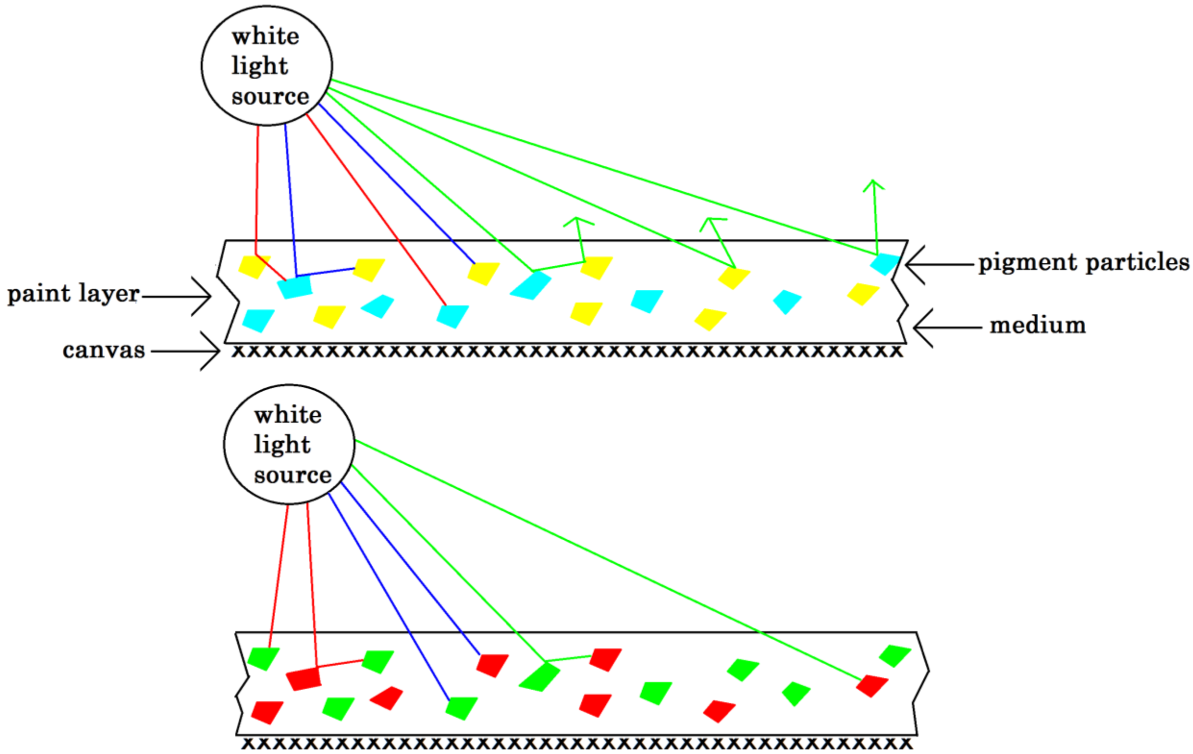

Figure 29 Subtractive colour mixing. Diagram by the author.

If we look at the top of Figure 29 (p. 120), we can see how yellow paint mixed with cyan paint makes green. This process is delineated in the table below:

Table 1 Light absorption (1)

Colours illumination made up of	First pigment: Yellow			Second pigment: Cyan			**Light emitted**
	Absorbs	Reflects		Absorbs	Reflects		
	Deep Blue	Green	Pillarbox Red	Pillarbox Red	Green	Deep Blue	
Pillarbox Red			reflected →	ABSORBED.			
Green		reflected →			reflected →		EMITTED
Deep Blue	ABSORBED.						
	First pigment: Cyan			Second pigment: Yellow			
	Absorbs	Reflects		Absorbs	Reflects		
	Pillarbox Red	Green	Deep Blue	Deep Blue	Green	Pillarbox Red	
Pillarbox Red	ABSORBED.						
Green		reflected →			reflected →		EMITTED
Deep Blue			reflected →	ABSORBED.			

The table below shows the lower paint layer of Figure 29 (p. 120), namely what happens when pillarbox red and green are mixed. As we can see, no light is emitted, making the mixture black.

Table 2 Light absorption (2)

Colours illumination made up of	First pigment: Green			Second pigment: Pillarbox Red			**Light emitted**
	Absorbs		Reflects	Absorbs		Reflects	
	Pillarbox Red	Deep Blue	Green	Deep Blue	Green	Pillarbox Red	
Pillarbox Red	ABSORBED.						
Green			reflected →		ABSORBED.		
Deep Blue		ABSORBED.					
	First pigment: Pillarbox Red			Second pigment: Green			
	Absorbs		Reflects	Absorbs		Reflects	
	Deep Blue	Green	Pillarbox Red	Pillarbox Red	Deep Blue	Green	
Pillarbox Red			reflected →	ABSORBED.			
Green		ABSORBED.					
Deep Blue	ABSORBED.						

The above diagrams and tables are simplified in that it groups all the colours in the spectrum into three groups, pillarbox red, green and deep blue, following the physiology of the eye. It should also be pointed out that the diagram does not make clear how light bounces around inside the paint film. If one looks at the diagram, one would think that a beam of light might make one bounce before exiting the film. One might wonder, then, why a beam of deep blue light might not hit a cyan particle and then simply exit the film. This would result in the paint ultimately giving off various quantities of all light. This is not, however, what happens. A beam of light will bounce off myriad particles before exiting the paint layer. As a result in the top diagram all the non-green light eventually meets a particle that absorbs it.

We can thus say that in the subtractive process the procedure is reversed, whereby the primary colours become the secondary colours and the secondary colours become the primary. For example, mixing cyan paint and yellow paint results in the particles of the cyan paint absorbing the pillarbox red light and the yellow particles absorbing the deep blue light, thus leaving one colour, green. This phenomenon provides artists with the possibility of creating all the colours needed for a painting from only three colours, cyan, yellow, and magenta. We might note the terminology sometimes used: pillarbox red, green and deep blue are the *additive primaries* or *subtractive secondaries*, while yellow, sky blue and magenta are the *subtractive primaries* or *additive secondaries*.

This procedure for mixing colours has remained the standard to the present day, but suffers from a number of flaws. Firstly, the colour wheel that most painters use (Figure 31, p. 124) is somewhat inaccurate. The main inaccuracy is that the red paint used as a 'subtractive primary' should in fact be a more blue-red colour, the name of which is usually given as 'magenta'. The correct colours for mixing paint are the same as those used in printing. These subtractive primaries are often included by printers in a test-strip on the edges of newspapers (Figure 31, p. 124). The correct ideal colour wheel is given, as best as is possible with reproduction technologies, in Figure 32 (p. 124).

Figure 30 Subtractive primary colours in a test strip on the edge of a newspaper.

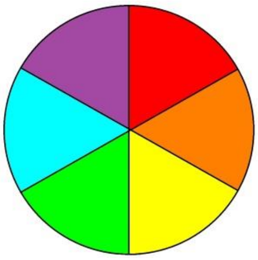

Figure 31 Traditional colour wheel. Diagram by the author.

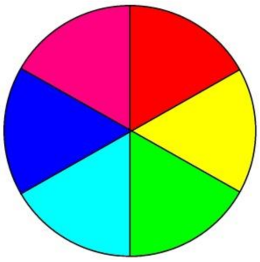

Figure 32 Modern colour wheel. Diagram by the author.

We might note that the names of the colours can also cause confusion. Physicists often call the additive primaries red, blue and green, while artists often call the subtractive primaries red, blue and yellow. To avoid this confusion I have called the *additive primaries* (*subtractive secondaries*) pillarbox red, deep blue and green, and the *subtractive primaries* (*additive secondaries*) magenta, cyan and yellow. I will thus refer to the cone cells as pillarbox red, deep blue and green. We might note in passing that one of these colours, magenta, is not spectral; additive mixtures of pillarbox red and green appear yellow, but there is also an actual wavelength for yellow, which triggers both the pillarbox red and green cones. Additive mixtures of pillarbox red and deep blue appear to us as a colour, magenta, but this does not actually exist as a separate colour, but is instead an artefact of our colour vision. Unlike our ears, which can detect different frequencies at the same time, any area of our eye can only see one colour at a time. Magenta, the non-spectral product of the stimulation of the pillarbox red and deep blue cones, thus cannot be seen as two separate colours and appears as one, fictitious colour (Lloyd, 2007, pp. 53–54). We might note here that in the more accurate colour wheel the complementary colour pairs are pillarbox red and cyan, green and magenta, and deep blue and yellow.

The notion of a systematic way of mixing colours has been of enormous influence since it was developed in art in the nineteenth century. We should note, though, that the processes of mixing colour are not at all new. As an example we might consider again Italian pre- and early-Renaissance art. The panels of the Jacopo di Cione's San Pier Maggiore Altarpiece (1370–1371), for example, used combinations of the blue pigment azurite and yellow lake pigments to make green (Bomford, Dunkerton, Gordon, & Roy, 1989, p. 42).

Furthermore, we should note that colour mixing is not confined to painting pictures. Subtractive colour mixing is also used in printing and painting houses. We should also note that additive colour mixing is used in theatrical lighting and on television and computer screens, as can be seen in Figure 4 (p. 53).

(Blake & Sekuler, 2006) (Bomford, Dunkerton, Gordon, & Roy, 1989, p. 42) (Clay Reid & Martin Usrey, 2013) (Eysenck & Keane, 2010) (Gage, 1993) (Gazzaniga, Ivry, & Mangun, 2009) (Livingstone M. , 2002) (Lloyd, 2007) (Newton, 1704) (Roy, 1985).

COLOUR VISION—OPPONENT PROCESS THEORY'S PILLARBOX RED/GREEN AND DEEP BLUE/YELLOW CHANNELS

At this point we might think that we have a complete understanding of the fundamentals of colour theory, and can begin to examine how this understanding can help us better analyse the problem of the truth of human vision. Colours can be arranged on a wheel, which in terms of physiology is most usefully divided up into six colours, which I have termed here deep blue, cyan, green, yellow, and pillarbox red. Magenta, the sixth colour, does not appear on the spectrum, and completes the wheel. Additive mixture creates magenta, cyan and yellow from pillarbox red, deep blue and green, while subtractive mixture creates pillarbox red, deep blue and green from magenta, cyan, and yellow. Chevreul's law of optical mixing allows colours to be made not only from pigment mixtures but optical mixture. Chevreul's law of simultaneous contrast points to the fact that contrasting colours and shades look stronger when juxtaposed; more saturated on less saturated, brighter on darker. As regards hues, the further away two colours are on the colour wheel the stronger simultaneous contrast will be.

While it would be impossible to disagree with most of this, the final statement seems less true. If we look at Figure 32 (p. 124) again, while the deep blue/yellow contrast is indeed strong, the pillarbox red/cyan and green/magenta contrasts are perhaps less so. Furthermore, there is another contrast that seems to be strong, namely pillarbox red/green, which are not even opposite on the wheel. It might be argued that the strongest contrasts are the deep blue/yellow and pillarbox red/green. This might lead us to the question of whether there is another aspect of colour that needs to be examined.

It is here that we might look at Hering's opponent process theory, namely that there are three 'channels' the signals pass through from the retina: the brightness channel, the pillarbox red/green channel, and the deep blue/yellow channel (Figure 33, p. 128).

Table 3 (p. 128) sets out how different coloured light stimulate the different types of cone cells in the retina, and how the three channels channel the resulting signals according to Hering's theory. Firstly, there is the brightness channel, which we will deal with in the next subsection. Secondly, there is the pillarbox red/green channel. This channel informs the brain whether the light is red or green. Thirdly, there is the deep blue/yellow channel. As we have seen in the colour wheel, green light mixed with pillarbox red light makes yellow light, due to yellow light activating both the pillarbox red and green cones. The deep blue/yellow channel informs the brain about whether the light is deep blue or yellow. This explains how we detect yellow, deep blue, pillarbox red, and green light. To detect cyan and magenta the brain relies on combining information from the pillarbox red/green and the deep blue/yellow channel. We can thus see that, if we accept Hering's theory, the strongest oppositions are pillarbox red/green and deep blue/yellow.

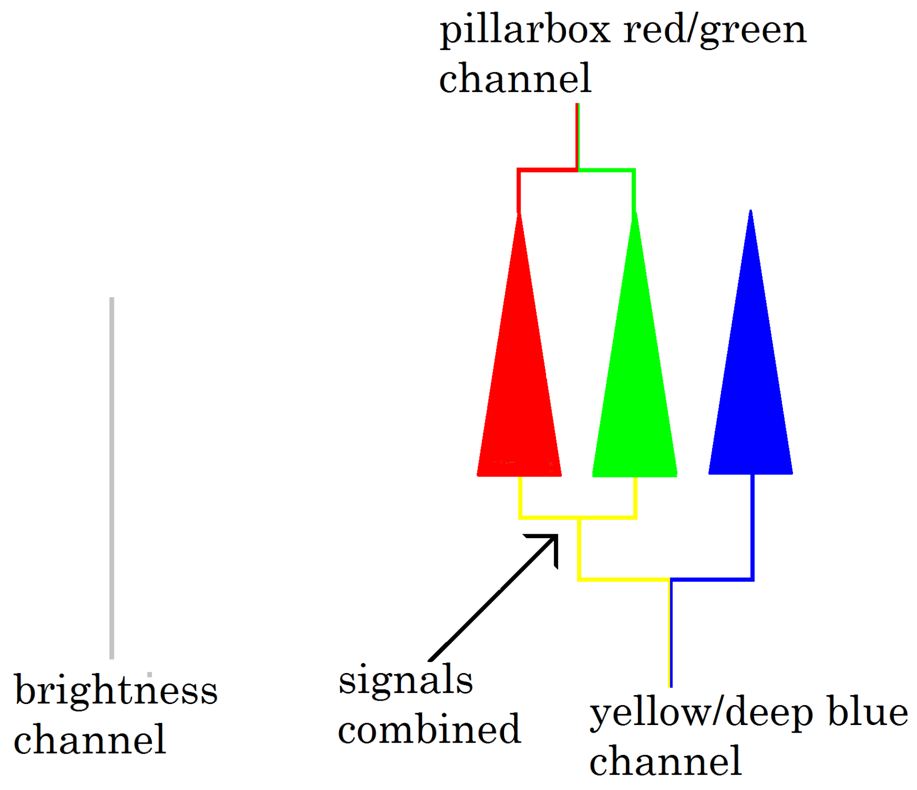

Figure 33 Diagram showing the initial processing of signals from the cones. Diagram by the author.

Table 3 Cones and neural paths activated (1)

Colour	Cones Activated			Paths Activated			
	Pillarbox Red	Green	Deep Blue	Pillarbox Red/Green		Yellow/Deep Blue	
				Pillarbox Red	Green	Yellow	Deep Blue
Pillarbox Red	•			•			
Yellow	•	•		•	•	•	
Green		•			•	•	
Cyan		•	•		•	•	•
Deep Blue			•				•
Magenta	•		•	•			•

There was for a long time disagreement about whether Helmholtz or Hering was correct about colour mixing. The consensus nowadays, illustrated in the above table, is that they were both correct (Eysenck &

Keane, 2010, pp. 58–59). As we noted earlier, the proposed process that brings Helmholtz and Hering together is Hurvich and Jameson's *dual-process* theory, developed by De Valois and De Valois. Helmholtz's trichromacy theory described the process in the retina. De Valois and De Valois were able to show that Hering's opponent process theory occurs in the geniculate nucleus, around half way between the eyes and the visual centre at the back of the brain (Hurvich & Jameson, 1957) (Mather, 2009) (De Valois & De Valois, 1975).

The above table explains how the theory of complementary colours works according to opponent process theory. If we replace the dots in any row of the table with blanks, and the blank spaces in that row with dots, ignoring the brightness channel, we obtain the complementary colour. A complementary colour is thus one that activates the channels in opposite way to the colour. Note that if both the pillarbox red and green cones are activated, pillarbox red/green channel does not respond, so it is as if it is switched off. If this were true, it occurs in an analogous way with the deep blue/yellow channel. Though dual-process theory is now the consensus opinion (Eysenck & Keane, 2010, pp. 58–59), we will see later that it still causes tremendous controversy (Pridmore, 2013) (Saunders, 2000).

If we accept opponent process theory, what can it tell us about art and culture? It has been argued that the four colours of Hering's theory, which I have called pillarbox red, green, yellow and deep blue, together with black and white, have a primacy in art. We will see, however, that the idea that humans have a primal sense of these colour channels needs to be investigated carefully.

We might make a preliminary examination of this issue here. Anthropologists Berlin and Kay developed the most influential theory of colour in culture that follows Hering's idea. Berlin and Kay argued that colour terminology follows a particular route of development (Berlin & Kay, 1969), basing their study partially on the work of anthropologist W.H.R. Rivers (1864–1922) (Rivers, 1901) (Saunders, 2000) (Slobodin, 1978). Rivers studied subjects from a number of cultures, including the Seven Rivers people, the Kiwai people, the Murray Islanders, and the Mabuiag people. Rivers argued that each of these people had a set of colour terms: for example, the Kiwai people had the terms red, white and black. Berlin and Kay extended Rivers' studies to come up with the following scheme. Berlin and Kay argued that colour terms are added to languages in particular stages. In the below each stage is given the standard number ascribed by Berlin and Kay:

I		II		III		IV		V		VI		VII
Black (Dark) White (Light)	→	Red	→	Green or Yellow	→	Yellow or Green	→	Blue	→	Brown	→	Purple, Pink, Orange, or Grey

Figure 34 Berlin and Kay's colour development progression. Diagram by the author.

It is notable that the first four colours after black and white are the colours that make up the colour channels.

Berlin and Kay's thesis has been influential, but also controversial. Hardin says that their work has 'by and large successfully passed the critical scrutiny of linguists and anthropologists' (Hardin, 1988, p. 156). Hyman is slightly more reserved in his praise, saying that 'some aspects of their work remain controversial, but the simple point that basic colors are not linguistic artefacts is not' (Hyman, 2006, p. 243n6). Others have heavily criticised Berlin and Kay's work, however. One example of such criticism is that of Barbara Saunders (Saunders, 2000).

Saunders looks back at the history of the academic environment and background in which Berlin and Kay worked. She notes that Hering's opponent process theory became popular around the time that Rivers performed his researches, and thus there was something of a self-fulfilling prophesy in Rivers' finding evidence of it.

Furthermore, she argues that Berlin and Kay did much the same thing. She argues that Berlin and Kay's eleven colour scheme is based on colour descriptions used by scientists of the early twentieth century, and Berlin and Kay made no attempt to analyse the possibility of cultural bias. She notes that the terms red, orange, yellow, green, blue, purple, pink and brown, all of Berlin and Kay's terms except for black, white and grey, were chosen by Lenneberg on the basis that, to quote Lenneberg, these are 'the most frequent colour terms in English' (Lenneberg & Roberts, 1956). Saunders argues that Berlin and Kay's paper had many errors, including notably that they did not use a random sample. This lack of a random sampling makes the accusation that Berlin and Kay simply looked for what they wanted to find, and disregarded information that did not fit their thesis, very strong.

Berlin and Kay's thesis must therefore be used very carefully, if any of it is to be accepted at all. We should note, however, that the Kiwai people, the Murray Islanders, and the Mabuiag people, all from the Pacific areas, do have as basic colour terms a selection from terms for black, white, red, green, yellow and blue. Also, we should note that Old Arabic's colour terminology was based on the colours in Berlin and Kay's first five colour stages (Borg, 2007, p. 266). Another example is the colour symbolism of the Druze religion. This religion dates to the eleventh century, and exists mainly in Lebanon, Syria and Israel. Believers of this religion have an interesting colour symbolism, made up of green for the mind ('al-'akl), red for the soul ('an-nafs), yellow for the word ('al-kalima), blue for the mental power of the will ('as-sabik), and white for materialisation of the mental power of the will ('al-tali) (Abu Izzeddin, 1984). Again we see the possibility that Hering's opponent process channels are present. We will examine this in more detail later.

(Abu Izzeddin, 1984) (Berlin & Kay, 1969) (Blake & Sekuler, 2006) (Borg, 2007) (Clay Reid & Martin Usrey, 2013) (De Valois & De Valois, 1975) (Eysenck & Keane, 2010) (Gazzaniga, Ivry, & Mangun, 2009) (Hardin, 1988) (Hurvich & Jameson, 1957) (Hyman, 2006) (Lenneberg & Roberts, 1956) (Livingstone M. , 2002) (Mather, 2009) (Pridmore, 2013) (Rivers, 1901) (Saunders, 2000) (Slobodin, 1978).

COLOUR VISION—OPPONENT PROCESS THEORY'S BRIGHTNESS CHANNEL

There has been a later addition to Hering's theory that we should consider, namely a proposed refinement to the black and white channel. Hering believed that there was a channel that dealt with black and white, but it has since been shown that it is not that simple. The brightness channel actually only takes information from green and pillarbox red cones. Figure 35 (p. 133) and Table 4 (p. 133) present a complete diagram and table of the opponent-process colour channels.

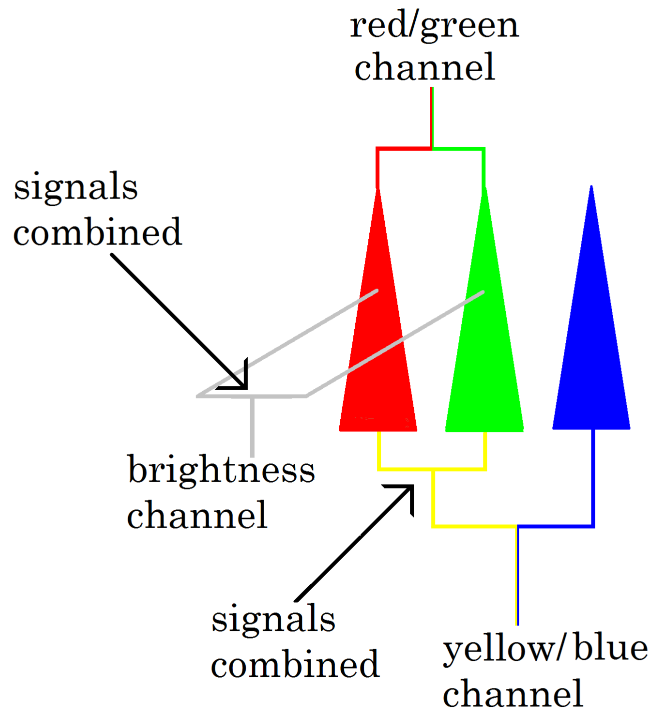

Figure 35 Complete diagram of how colour channels work, including the brightness channel. Diagram by the author.

Table 4 Cones and neural paths activated (2)

	Pillarbox Red	Green	Deep Blue	Brightness	Pillarbox Red/Green		Yellow/Deep Blue	
					Pillarbox Red	Green	Yellow	Deep Blue
Pillarbox Red	•			•	•			
Yellow	•	•		• •	•	•	•	
Green		•		•		•	•	
Cyan		•	•	•		•	•	•
Deep Blue			•					•
Magenta	•		•	•	•			•

Yellow light stimulates two receptors in the brightness channel, and as a result has two dots: deep blue stimulates neither, and as a result has no brightness channel dots. It is interesting to note how the stimulation of the brightness channel affects the apparent brightness of the colours. Brightness can be thought of as the product of intensity and frequency, as according to quantum mechanics frequency is proportional to energy (Gamow, 1966). However, this does not appear to be the case when we look at colours. Blue tends to appear darker than yellow, even though the energy of blue light is much greater than yellow. It is the colour channels that explain this. Table 5 (p. 134) shows how yellow is the apparent brightest, due to both brightness path being activated, while pillarbox red, green, magenta and cyan all stimulate one brightness path, and deep blue stimulating no path. This has been used to explain why yellow appears particularly bright while deep blue appears particularly dark.

Table 5 Receptor groups activated

Colour	Brightness Path Receptors Activated		Total Number of Receptor Groups Activated
	Pillarbox Red	Green	
Yellow	•	•	2
Pillarbox Red	•		1
Green		•	1
Magenta	•		1
Cyan		•	1
Deep Blue			0

A possible application of how this brightness channel affects art can be seen in Duccio's *Virgin and Child with Saints* (c.1278–1319. London: National Gallery), notably for among other things the intense ultramarine of the Virgin's mantle. We will see that the creation of this mantle presented Duccio with a peculiar problem associated with modelling form, and specifically the creation of highlights and lowlights. Three of the most important ways of creating highlights and lowlights, and thus in modelling form, that we see in Italian pre- and early-Renaissance art are up-modelling, down-modelling, and up-and-down-modelling. Up-modelling involves using a pure colour for low-lights, and adding increasing amounts of white to create lighter shades. Down-modelling also starts with a pure colour, but instead uses it as the lightest colour, and adds increasing amounts of black to create low-lights. Finally, up-and-down-modelling involves using the pure colour for the mid-tone, and adding white for highlights and black for lowlights. An example of up-modelling can be seen in the yellow-clothed horse riders in Jacopo di Cione's *Crucifixion*, while an example of down-modelling can be seen in the Virgin's blue mantle in Duccio's *Virgin and Child with Saints*, and an example of up-and-down-modelling can be seen in the flesh tones in the Master of Saint Francis's crucifix (c.1270–90. London: National Gallery).

It is with the yellow of Jacopo di Cione's horse riders and the Virgin's blue mantle in the Duccio that we see how the brightness channel can affect modelling. In order to model form the down-modelling needs to be darker than the up-modelling, with the mid-tones in-between. Consider first Jacopo di Cione's horse rider. White light is composed of more different spectral colours than yellow, but because the deep blue light does not trigger the brightness channel, only the pillarbox red and green cones are triggered. We might note that yellow also triggers the pillarbox red and green cones, and as a result white appears no brighter than yellow. Using yellow for the lowlights and white for the highlights results in the object depicted lacking form, as can be seen in Jacopo di Cione's horse riders. We should also note that the desaturation caused by the white also contributes to the problem, and results in the yellow appearing to come forward in front of the white. The only chance of the white appearing to come forward is its brightness, which as we have seen cannot happen as the yellow appears as bright as the white.

In the Virgin's mantle of the Duccio we see the opposite problem. Ultramarine is a very pure blue, and its purity of blue makes it very dark, because there is little to stimulate the pillarbox red and green cones of the brightness channel. We can see this in Figure 36 (p. 138), Figure 37 (p. 138) and Figure 38 (p. 139). If we compare Figure 37 (p. 138) and Figure 38 (p. 139) we see that the spectrum for ultramarine and the blue cones match each other very closely. The only deviation is some red, though it is at the far end of the spectrum and thus does not stimulate any of the cones very strongly. The strongest stimulation of the red light is the pillarbox red ('L') cone, and even that is not very strongly stimulated. As a consequence ultramarine can be said to be a very close match for the stimulation of the blue cone, and the blue cone alone.

As it is largely the blue cone that is stimulated by ultramarine, we can note that the pillarbox red cones and the green cones are not stimulated very much at all. Now as we have seen, the brightness channels consist of the pillarbox red and green cones, and as a result ultramarine will not stimulate the brightness channel very much at all, making ultramarine very dark.

How does this affect Duccio's modelling of the Virgin's mantle? Let us consider Figure 37 (p. 138) and Figure 38 (p. 139) again. Note how white light will stimulate the pillarbox red and green channels very strongly, making white light appear very bright. We might think that as white appears brighter than ultramarine, we would have the opposite situation of the yellow horse riders above, and thus white modelling on ultramarine would be very successful. However, any attempt to use white as a highlight for ultramarine will make a very strong brightness differential between the lowlights and the highlights, rather than the much subtler differences needed in modelling.

We can see the problems this causes in artworks where the artist has attempted to use white in the highlights of ultramarine. Consider, for example, the 1407–9 *The Coronation of the Virgin* (London: National Gallery) by Lorenzo Monaco (c.1370–c.1425). The artist has attempted to up-model the Virgin's mantle, Christ's robe, and the lower robe of the central angel at the bottom. The artist wanted to maintain the purity of the ultramarine, and not desaturate it with white. However, we can see that there is something unsuccessful about this in Christ's robe, despite the virtuoso drawing. The white highlights are too bright for the dark ultramarine, and as a result the modelling is less successful overall. As with the yellow horse riders that we looked at before this is exacerbated by the white desaturating the ultramarine, making the lowlights appear to come forward in front of the highlights.

We might note that where the artist does not use pure ultramarine, as in the lower angel, the modelling is much more successful. We might note that Christ's right leg is more successfully modelled than his left, because the artist has used less white. However, if the artist had only used this low level of white across the whole figure, including Christ's left leg, the overall figure would be particularly flat.

How does Duccio approach this problem in the Virgin and Child with Saints? Duccio down-models the Virgin's mantle with black. This results in a less virtuoso modelling than Christ's robe in the Lorenzo Monaco, but while less ambitious, it is more successful overall. The down-modelling does not stimulate the brightness channel more than the mid-tones, and as a result there is no large disparity in brightness, resulting in a more subtle modelling that preserves the purity of the ultramarine. We should note, though that while Duccio's modelling appears more successful generally, it nevertheless lacks Lorenzo Monaco's clear description of volumetric form. This implies that the white up-modelling, black down-modelling, or even white-and-black up-and-down-modelling will tend to be less successful in modelling form in ultramarine.

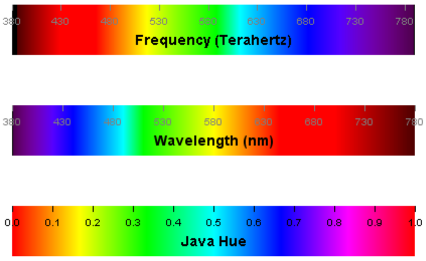

Figure 36 **Chart of frequency and wavelength of the visible spectrum. media.pcwin.com/images/screen/wavelength-29212.png**

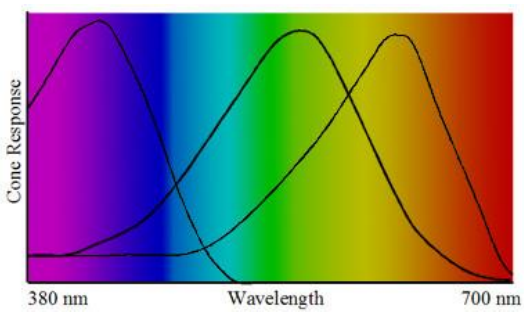

Figure 37 **From left: the 'S' cone curve (short wavelength, what I have termed the deep blue cone), the 'M' cone curve (medium wavelength, what I have termed the green cone), and the 'L' cone curve (long wavelength, what I have termed the pillarbox red cone). www.ronbigelow.com/articles/color-perception-4/perception-4.htm**

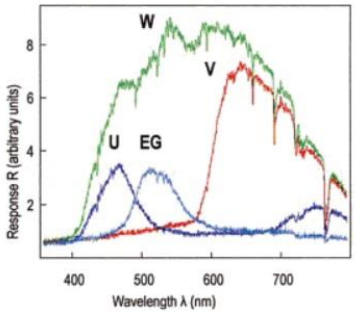

Figure 38 Chart of wavelength spectrums for various pigments. W is white card, and U is ultramarine. From (Brebbia, Greated, & Collins, 2011, p. 130).

Cézanne's *Mountains in Provence* (c.1886) provides an example of how ultramarine's property of having both darkness and intense colour makes it useful if an artist wishes to create a colourful shadow. Cézanne used ultramarine, together with a little lead white and black to create the small area of intense dark blue shadow between the rocks on the centre left of the picture (Roy, 1985, p. 17). The majority of the dark shadows in the painting are black, so the use of the ultramarine allowed Cézanne to vary the colour without varying the brightness.

It is also interesting to recall the work of the anthropologist Rivers from earlier. We will see that Rivers' ideological commitment to his view of Hering's opponent process theory caused him to miss an important observation. Rivers' studies showed that subjects of some cultures he observed did not form a distinction between black and blue. He wrote:

> … the 'insensitiveness' to blue might depend on the lack of development of some physiological substance or mechanism … or it may only depend on the fact that the retina of the Papuan is more strongly pigmented than that of the European

(Rivers, 1901), quoted in (Saunders, 2000)

We saw earlier that Hering believed the brightness channel was made of white and black, whereas the scientific consensus now is that the brightness channel is made of pillarbox red and green only, and notably omits deep blue. That black and blue would be conflated into one colour is better explained by this, instead of Rivers' notion of pigmentation.

Finally, we will note an example of an artwork that involves a range of different approaches, namely Henri Matisse's c.1951 painting *Vegetables (Végétaux)*. Matisse notably juxtaposes white on darker colours, which accentuates the white. Like Renoir he also juxtaposes blue and orange. Most notably, though, he places a green plant motif made of thin lines on a red background. He thus creates simultaneous contrast with a large contour in the minimum area, thus making the contrast particularly noticeable. The contrast in question is one of Hering's opponents, red and green. The two qualities interact making the bottom left area of the picture almost appear to vibrate.

(Blake & Sekuler, 2006) (Brebbia, Greated, & Collins, 2011) (Clay Reid & Martin Usrey, 2013) (Eysenck & Keane, 2010) (Gazzaniga, Ivry, & Mangun, 2009) (Livingstone M. , 2002) (Rivers, 1901) (Roy, 1985) (Saunders, 2000).

COLOUR VISION—MUNSELL

A final important aspect of contemporary colour theory that we will need to examine in order to evaluate the notion of the perception of colour is Munsell's colour system. This theory has been of enormous interest in vision (Cochrane, 2014). In order to explain its value in explaining art we will use it to examine the work of the great Venetian colourists, notably Veronese's 1563 *Wedding Feast at Cana*.

In sixteenth century Venice a revolution occurred in pictorial colour. Artist Bridget Riley describes how this revolution began with reference to two paintings by Titian (c.1488/1490–1576), his 1510 *St Mark Enthroned and Other Saints* (Figure 39, p. 141) and his 1518 *The Assumption* (Figure 40, p. 142). In *St Mark Enthroned and Other Saints* the blue of the drapery that covers St Mark's knees is difficult to place spatially; it appears to float out in front of the saint, rather than sit with the figure. In the later *The Assumption* Titian solves this problem by unifying the colours of the objects depicted by basing the colour of each on either a variation or contrast of a warm rose. Titian's solution to this problem starts a revolution that propelled Western art on a voyage of discovery that continued into the twentieth century (Riley, 1995, pp. 32–33).

Figure 39 Titian. *St Mark Enthroned and Other Saints.* Santa Maria della Salute, Venice, 1510.

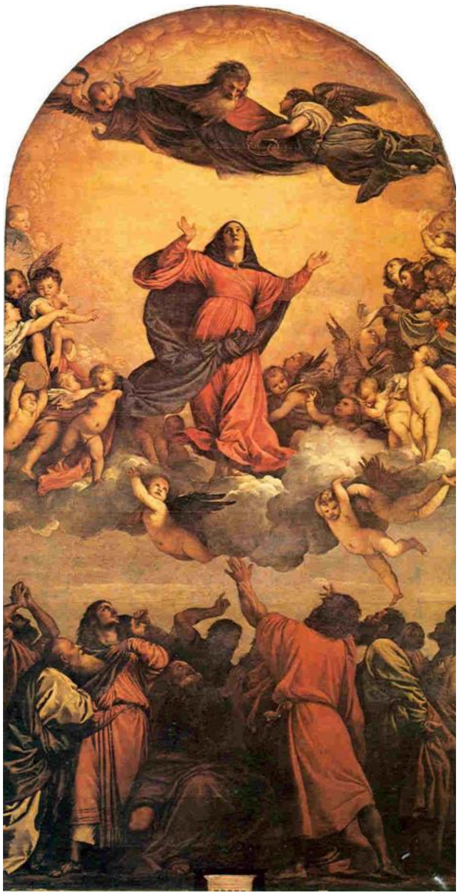

Figure 40 Titian. *The Assumption.* Santa Maria Gloriosa dei Frari, Venice, 1518.

A later Venetian artist who developed the technique of pictorial colour was Paolo Veronese (1528–1588). If we look at his 1563 *The Wedding Feast at Cana* (Figure 41, p. 143), we see that it is a riot of colour without an underlying colour theme, unlike Titian's *The Assumption*, and yet Veronese creates a convincing representation of space. It is here that we will see how illuminating Munsell's system can be.

Figure 41 Paolo Veronese. *The Wedding Feast at Cana.* Louvre, Paris, 1563.

Munsell was an American art teacher who created the Munsell Colour System. This system involves describing each colour in three ways: hue (whether green, blue, scarlet or other), tone (how bright or dark) and saturation (how pure or muddy) (Figure 42, p. 144) (Munsell, 1905). Munsell was not the first to divide colour in this way. He based his system on the work of colour theorists such as Philipp Otto Runge (1777–1810). Munsell's work would later be given greater scientific precision by Friedrich Wilhelm Ostwald (1853–1932), but nevertheless Munsell's work remains the basis for later theories (Gage, 1993). Munsell used numbers in his system in order to do away with the imprecision of words such as green, blue, bright and muddy, but in our investigation of Veronese it is the relations of the hues that are of importance, so we will stick to more familiar terms such as 'red next to gold', 'more muddy than' and 'darker than'.

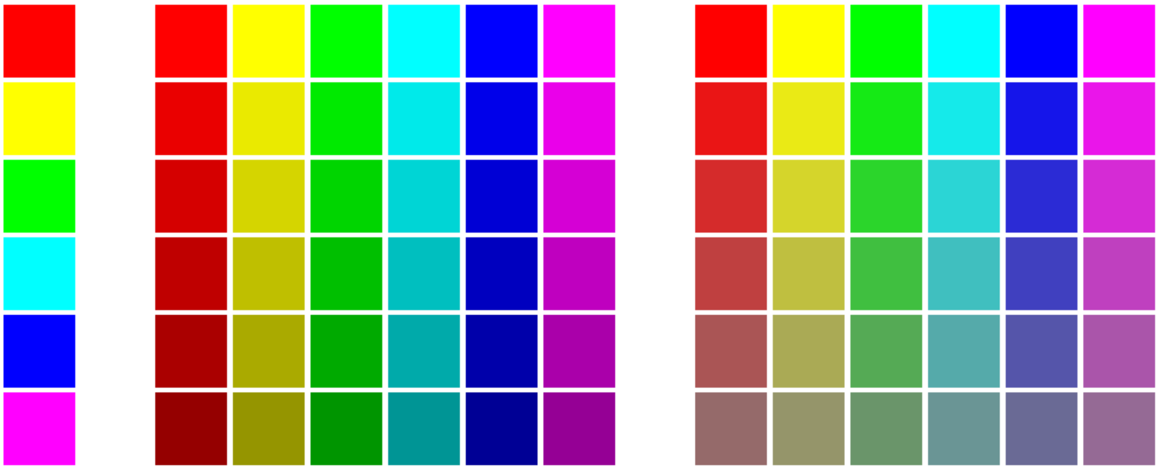

Figure 42 Munsell's colour system. From left: Hue • Tone • Saturation. Diagram by the author.

This chart can also be put in three dimensions, as in Figure 43 (p. 144).

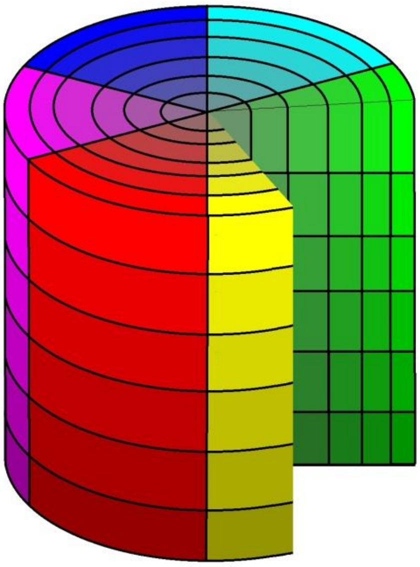

Figure 43 Representation of the three features of colour in three dimensions. Hue: around the circle. Tone: increasing from bottom to top. Saturation: increasing as circle radiates out from the centre. Diagram by the author.

Munsell's distilling of the properties of colour provides a precise description of how colours appear to advance or recede from the picture surface (though we will see that many disagree with his interpretation). If we recall the discussion of the dual-process theory we saw earlier, certain hues appear brighter than others. If we start from the left of Figure 29 (p.

120), we observe that blue seems to recede, while red and green comes forward, and yellow comes forward even further. Furthermore, we might note that dark tones appear to recede, while light tones tend to come forward. Muddy colours tend to recede, while pure colours tend to come forward. Moreover, looking at the charts we see there is a dynamic interaction between the properties.

Armed with Munsell's system, we can now examine *The Wedding Feast at Cana* to discover how Veronese used the properties of colour to depict space. We should note that, of course, Veronese had no knowledge of Munsell's system, but that Munsell's system is useful in delineating and explaining Veronese's technique. The most striking property of Veronese's colour is the use of saturation. The columns and sky in the background are notably washed out, there is more colour on the figures of the upper balcony, while the strongest colours are reserved for the clothes of the figures in the foreground. We should note, though, that there is a similarity to Titian's *The Annunciation* in that while Veronese scatters colours over the painting, he unifies areas of the painting by maintaining a constant level of saturation in each area. Greens and yellows are unified as emerald greens and bright yellows in the foreground, and earth greens and ochres on the balcony, and the orange and yellow stonework in the foreground become pale cream and white in the background. Veronese's approach to both hue and tone is more subtle, and interlinked. The blue of the sky is bright, and thus comes forward, pushing its way in front of the dark grey balcony, but the blue itself recedes behind the dazzling colours of the foreground. Thus Veronese created a sky that sits behind the figures, but arches above to create a canopy over the scene.

(Blake & Sekuler, 2006) (Clay Reid & Martin Usrey, 2013) (Cochrane, 2014) (Eysenck & Keane, 2010) (Gage, 1993) (Gazzaniga, Ivry, & Mangun, 2009) (Livingstone M. , 2002) (Munsell, 1905) (Riley, 1995).

THE CONFLICTING IDEOLOGIES OF COLOUR

Having examined the role colour plays in depiction, we can now turn to examining the underlying ideologies. As we touched on when looking at Berlin and Kay's work, colour theory is a mass of such conflicting ideologies. The most important of these conflicts to us here is the nativism/empiricism debate. This debate goes back a long time, and is often presented in terms of the conflict between Descartes and Locke. Descartes' philosophy can be summed up by his phrase *'cogito ergo sum'*, 'I think therefore I am'. Descartes placed the emphasis on prior knowledge in the mind, with the most important form being mathematics. Locke meanwhile argued that the mind is a *'tabula rasa'* or 'blank slate', in contrast placing the emphasis on sensory experience (Descartes, 1637) (Locke, 1690).

Though Locke believed that it was sensory experience that provided us with ideas, he did not believe that all sensory experience was equal. He described properties such as smell and colour as 'secondary qualities', which are not properly 'REAL' in the way that 'primary qualities' such as number or mass are:

> 17. The ideas of the Primary alone really exist.
>
> The particular bulk, number, figure, and motion of the parts of fire or snow are really in them,—whether any one's senses perceive them or no: and therefore they may be called REAL qualities, because they really exist in those bodies. But light, heat, whiteness, or coldness, are

> no more really in them than sickness or pain is in manna. Take away the sensation of them; let not the eyes see light or colours, nor the can hear sounds; let the palate not taste, nor the nose smell, and all colours, tastes, odours, and sounds, AS THEY ARE SUCH PARTICULAR IDEAS, vanish and cease, and are reduced to their causes, i.e. bulk, figure, and motion of parts.

(Locke, 1690) Book 2, Chapter 8, Section 17, Locke's use of capitals

With our contemporary knowledge of chemistry and physics we might say that smell is the detection of airborne chemicals, and, important for our discussion here, colour is the detection of the wavelengths/photon energy of light, so we might be tempted to dismiss Locke's idea of secondary qualities as a result of his more primitive understanding of science, and 'upgrade' smell and colour to the status of primary qualities and say that they 'really exist in … bodies'.

Hyman notes that there are two current viewpoints on colour: nativism, the idea that concepts are innate, and empiricism, the idea that concepts are acquired by learning through the environment (Hyman, 2006, p. 14). If qualities such as colour 'really exist in … bodies', and are thus primary qualities as twenty-first century science might teach us, colour concepts would thus be empirical.

We would, however, be wrong in assuming that everyone in the contemporary world thinks like this. Hyman provides a number of surprising examples of colour nativists: John Gage writes that 'Newton … showed that colour is indeed illusionary'; psychologist Stephen Palmer writes that 'colour is a psychological property of our visual experiences when we look at objects and lights, not a physical property of those objects and lights'; neurobiologist Semir Zeki writes that colour 'is a property of the brain, not of the world outside' (Hyman, 2006, p. 14). Hardin, on the other hand, observes that many contemporary philosophers are indeed colour empiricists (Hardin, 2003, p. 191). Given the dissent on this topic, however, we will need to examine this issue in detail.

We can see the opposing ideologies of empiricism and nativism in Helmholtz and Hering's theories, which as we saw earlier were originally thought to be in competition. Helmholtz's trichromacy theory is primarily concentrated on how we can see the spectrum of colours of the physical world. Hering's theory, meanwhile, deals with what happens to the information further on in the brain. Helmholtz's theory describes a mechanism whereby the eye can detect a range of physical colours, whereas Hering's theory makes predictions about mental interpretations, such that it is impossible to see a red-green, or a bluish-yellow. Helmholtz and Hering thus had competing scientific ideologies. Helmholtz can be seen as an empiricist, meaning he believed that knowledge is tied to experience, while Hering can be seen as a nativist, meaning he believed that concepts are 'hard-wired' into the brain from birth.

To add another level of complexity to the debate, Hering's theory of colour channels has recently been criticised. Pridmore, for example, argues that Hurvich and Jameson's dual process theory is wrong, and that the colour channels in the geniculate nucleus correspond to what I have called pillarbox red, green, and deep blue, and not the pillarbox red/green, yellow/deep blue, and brightness channels (Pridmore, 2013).

In this subsection we will examine the various arguments surrounding colour, in relation to the nativist/empiricist debate. This will allow us to answer the question posed by this section, namely whether the visual system allows us to perceive sensory input accurately. Nativists are more sceptical of this, in contrast to empiricists. Due to it being such a battleground, we will be able to study the relevant issues most clearly via the topic of colour. The above subsections concerning colour will provide us with evidence to facilitate this debate.

Though, as we saw earlier, the current scientific consensus today is that there is no contradiction between Helmholtz and Hering's theories, we see in contemporary discussions of colour vision the empiricism and nativism debate continuing. Consider a recent paper on colour vision by C. L. Hardin. Hardin argues against the belief that colours are physical things, and that we can perceive those physical things. He writes:

> Because the eye contains only three types of photopigment, it has but three degrees of freedom with which to represent light spectra. To disentangle the spectrum of the illuminant from the spectrum of the surface under a wide variety of conditions, it would have to have five. Perfect color constancy is therefore impossible, and the eye must rely on a number of tricks to discount the illuminant as well as it does.

(Hardin, 2003, p. 192)

Hardin downplays the eye's ability to detect a range of spectral colours, saying that the eye 'has but three degrees of freedom with which to represent light spectra'. However, he does not mention the fact that with these three degrees of freedom the eye can detect upwards of 2.3 million colours, by combining the varying information from adjacent cones of different types (Jacobs, 2009) (Pointer & Attridge, 1998).

Might we, then, be tempted to dismiss the nativist view, then, and go for the empiricist view instead? Before making our decision, let us for a moment consider our perception of the energy of the light that hits our eye.

We noted above that Hering identified three channels, the pillarbox red/green channel, the deep blue/yellow channel, and the brightness/darkness channel. It is the brightness/darkness channel that is of relevance here. Long after Hering, it was observed that the brightness channel only takes input from the pillarbox red and green cones, not the deep blue. Consequently, pure blue tends to appear darker than other colours, despite quantum mechanics telling us that blue light has higher energy levels (Blake & Sekuler, 2006) (Gamow, 1966). As a consequence, we might note that our perception of blue as dark is an artefact of our colour vision, and not of the physical nature of light. Our perception is, then, somewhat deceived when it comes to perceiving brightness, leading us perhaps to go back to the nativist view.

Which, then, will it be: nativism or empiricism, or perhaps a combination of the two? In his book *The Objective Eye* philosopher John Hyman presents a combination, in the form of a 'qualified objectivism' (Hyman, 2006). He delineates three components to the issue. Firstly, he asks whether colour is a real, physical thing; secondly, he asks why, if colour is real, has there been so much debate about the issue; and thirdly, he asks how can we reconcile the problems of the disparities of perception with his posited belief in the reality of colour.

Hyman begins his argument with Galileo (Hyman, 2006, pp. 11–29). Hyman notes Galileo's belief that objects can be said to have size, shape, and position, but that other qualities, such as taste, odour, and colour, are not real properties. Galileo's lack of belief in the real, physical nature of these second properties is due to his belief that they are merely the action of objects on the senses. Galileo argued:

> if the perceiving creature were removed, all these qualities [tastes, odours, colours] would be removed from existence

(Galilei, 1929–1939, pp. 347–348), quoted in (Hyman, 2006, p. 12)

Hyman dismisses Galileo quickly, by noting the difference between *seeing red* and *redness*:

> It is also true that the experiences of tasting sweetness and seeing red could not occur if there were no sentient animals alive to have them. And it is true that we should not predicate tasting sweetness and seeing redness of a grape. But it does not follow that we should not predicate sweetness or redness of it either.

(Hyman, 2006, p. 13)

Hyman is still left, though, with the problem of the somewhat arbitrary way our colour terms (red, green, etc.) group wavelengths (Hyman, 2006, p. 31). We might agree with Hyman that 'redness' might go on after the death of all sentient creatures, while noting that 'seeing red' dies with the final sight of blood by the final creature. 'Red', though, as Hyman admits, as a concept does not 'carve nature at the joints', as Plato might have put it ((Plato, c.370 BCE, pp. 265d–266a), quoted in (Hyman, 2006, p. 44)). 'Red' is just a word that denotes electromagnetic waves with wavelengths between 620–740 nm. The arbitrariness of this definition might remind us of Nelson Goodman's colours 'grue' and 'bleen': an object being 'grue' if and only if it is observed before a given time and is green, or else is not so observed and is blue, or is ‘bleen’ if and only if it is observed before a given time and is blue, or else is not so observed and is green (Goodman, 1955).

It is here, then, that nativists might strike back, noting that to understand the concept ‘red’ one must understand the working of the human visual system. To the example of the arbitrariness of colour names nativists might add the fact that the colour blue, which as we noted often appears quite dark in comparison to say yellow, has according to quantum theory more energy.

Hyman does not reject such arguments made by nativists, but neither does he collapse into unmitigated scepticism about the reliability of the senses. He argues instead that ‘the invisible structure of matter causes us to see an object’s color: its color does not have this effect on us itself’ (Hyman, 2006, p. 56). He makes the point that colour cannot simply appear in the mind; that something stimulates the visual system to see ‘colour’ means there must be some property out there that causes us to see. He notes:

> If this is right, the correct view about colors can be described as a qualified objectivism, since colors are in this sense logically independent of our perceptions of color but not epistemically independent of them. Experience is the highest court of appeal where the colors of objects are concerned, but it does not and cannot fix the facts.
>
> (Hyman, 2006, p. 56)

Following Hyman, then, we might conclude that ‘red’ is a word that denotes electromagnetic waves with wavelengths between 620–740 nm. If we see a ‘red’ object, we can say something definite about it physically, namely that it has either emitted or reflected electromagnetic waves of wavelengths between 620–740 nm. This provides us with evidence that the object seen is one of the class of objects that emit or reflect such wavelengths, such as blood, or a particular compound of the metal cadmium. This aids the viewer in empirically identifying the object.

We are still left, however, with the issue of how the colour red is ‘carved’, as Plato might have put it. It is here that we need to turn to nativism, though we will see that controversy is not behind us.

Nativism in colour theory is found most notably in the work of anthropologist Brent Berlin and linguist Paul Kay that we examined earlier. To recap, their 1969 study *Basic Color Terms: Their Universality and Evolution* proposed that all cultures develop the same basic colour terms (Berlin & Kay, 1969). They furthermore proposed that cultures develop terms in the following order:

I		II		III		IV		V		VI		VII
Black (Dark) White (Light)	→	Red	→	Green or Yellow	→	Yellow or Green	→	Blue	→	Brown	→	Purple, Pink, Orange, or Grey

Figure 44 Berlin and Kay’s colour development progression. Diagram by the author.

We might note that in stages I to V, we see the inspiration for Berlin and Kay’s work: black, white, red, green, yellow and blue make up the colours in Hering’s opponent process theory.

As perhaps might be expected with so bold a theory Berlin and Kay’s work caused huge controversy. Barbara Saunders, who we met earlier, spoke of those who believed in Berlin and Kay’s findings in these terms:

> This suspension of critical faculties must be put down to such factors as weariness with the Relativist Zeitgeist, local factional politics,

> congruence with structuralist and Chomskian principles, the status of Berkeley Anthropology and a sycophantic adulation of scientistic methodology.

(Saunders, 2000)

Berlin and Kay replied vigorously:

> That S&vB [Saunders and Van Brakel, another critic] could understand the text of BCT [Berlin and Kay's Basic Color Terms] only by assuming that its authors lied about their assumptions is not a compelling argument that the authors of BCT lied about their assumptions. Others have understood that text without making this assumption.

(Berlin & Kay, 1997, p. 3)

The above arguments allow us to discern certain features that underlie this debate. Berlin and Kay's theory was based on the assumption that there are psychophysiological constants in all humans. It is not necessary to argue that Berlin and Kay lied to observe that they, of course, made assumptions. However, Berlin and Kay must also concede a point to Saunders, namely that their assumptions do involve cultural bias, as all assumptions must. Saunders argues that the first five stages of Berlin and Kay's proposed scheme of colour evolution were chosen by them due to enthusiasm for the work of Hering. She proposes that there was something of a self-fulfilling prophesy in Berlin and Kay finding these colours occurring in cultures. She argues that Berlin and Kay's paper had many errors, including most notably that they did not use random samples. This lack of random sampling forms the basis of her argument that Berlin and Kay simply looked for what they wanted to find, and disregarded information that did not fit their thesis (Saunders, 2000).

It is here we can see another objection to nativism, namely that the human mind is culturally conditioned. This is slightly different to the issue of nativism vs. empiricism, in that it brings into the mix the idea that concepts of the visual system can be passed from mind to mind via culture.

We might begin our examination of this new twist by noting that there have been counter-arguments to Saunders and Van Brakel. Hardin, for example, writes:

> Van Brakel leaves one with the erroneous impression that the study of the neurophysiology of colour perception is in a state of general disarray, that there is scant physiological backing for functional Opponent Process schemes proposed by psychophysicists, and that these schemes have thus been rendered highly doubtful.

(Hardin, 1993, p. 140)

> Ewald Hering is arguably the Galileo of colour-vision theory, and it is difficult to find a contemporary colour scientist for whom Hering's Opponent Process theory does not provide a cornerstone for his thinking about the subject.

(Hardin, 1993, p. 141)

How reasonable is this? Even if we were to accept opponent process theory, and believe that there is no disarray in colour neurophysiology, would it still be true to say that opponent process theory is a 'cornerstone' for colour science?

Let us first ask the question of what opponent process theory actually argues about vision. Firstly, it states that colours are funnelled into the brain in three channels. This explains why red, green, yellow, and blue seem to be fairly important in colour terminology. It can also explain the choice of colours in the colour symbolism of the Druze religion that we saw earlier. Another example can be seen in our earlier observation, shown in Figure 35 (p. 133), that the lack of contribution to the brightness channel explains why blue tends to appear particularly dark.

We can see, then, that if opponent process theory is true it indeed does tells us something about colour. However, its explanatory power is, perhaps, limited. It does not explain why, for example, the Druze religion chose green to symbolise the mind ('al-'akl), red to symbolise the soul ('an-nafs), and so on. Nor does it explain English terms such as gold, silver, and notably blonde, which can be applied to a large number of different hair colours.

Hering's work was one of the motivations for Berlin and Kay's theory, but we should now examine the theory's other important aspect. Philosopher Jacques Derrida has written about this aspect in other contexts, namely the dominance of speech in Western discourse (Derrida, 1967, 1997). We might examine this by looking at the Sapir–Whorf hypothesis, a proposition named after linguists Edward Sapir (1884–1939) and Benjamin Lee Whorf (1897–1941). The Sapir–Whorf hypothesis proposes that language shapes human thought. Sapir suggested:

> Even comparatively simple acts of perception are very much more at the mercy of the social patterns called words than we might suppose. … We see and hear and otherwise experience very largely as we do because the language habits of our community predispose certain choices of interpretation

(Sapir, 1929, p. 210)

Notably Paul Kay, one of the authors of the Berlin and Kay thesis, wrote:

> A more cautious Whorfianism seems to be supported by the results reported here and by other contemporary research on color. In this view we acknowledge that there are constraints on semantic differences between languages, so we accept not an absolute linguistic relativity but a modest version.

(Kay & Kempton, 1984, p. 77)

We should note that Berlin and Kay were not the only researchers to study colour naming. Berlin and Kay's study was foreshadowed by the work of anthropologist Rivers, who we met earlier in this section in the subsection 'Colour Vision—Opponent Process Theory's Pillarbox Red/Green and Deep Blue/Yellow Channels' (p. 126). Rivers asked member of cultures to sort coloured tiles. He discovered that members of cultures who only have terms for black, white and red sorted blue and green tiles into the same pile, implying they can only perceive the colours black, white, and red (Rivers, 1901). However, later researchers found that in some cultures, even though they might perform the sorting task in terms of their language colours, the participants were able to make discriminations of other colours (Davies & Corbett, 1976). It has thus been concluded by cross-cultural psychologists that colour terms are mainly about the communication of colour information (Phillips W. , 2011, p. 161).

A final facet of the debate can be seen by recalling the work of Pridmore that we noted earlier. He writes:

> Valberg recalls that "it became common among neurophysiologists to use colour terms when referring to opponent cells as in the notations 'red-ON cells', 'green-OFF cells' .... In the debate .... some psychophysicists were happy to see what they believed to be opponency confirmed at an objective, physiological level. Consequently,

> little hesitation was shown in relating the unique and polar colour pairs directly to cone opponency. Despite evidences to the contrary .... textbooks have, up to this day, repeated the misconception of relating unique hue perception directly to peripheral cone opponent processes. The analogy with Hering's hypothesis has been carried even further so as to imply that each colour in the opponent pair of unique colours could be identified with either excitation or inhibition of one and the same type of opponent cell." Webster et al. and Wuerger et al. have conclusively re-affirmed that single cell spectrally opposed responses do not align with unique-hue opponent colours.

(Pridmore, 2013, p. 9)

We might thus note that the controversies about Berlin and Kay's thesis stretch down to doubts about Hering's theory itself.

CONCLUSION

Colour, then, has been a contentious issue. We can, however, affirm what Hyman calls a 'qualified objectivism'; namely that it is reasonable to state that light is a part of the physical world, and that what we call 'colour' can be said to be our perception of these waves/particles. Words such as 'red' and 'yellow' each describe a range of wavelengths, and to some extent the ranges may vary between different people. Furthermore, sometimes colours might be misidentified: mixtures of red and green light might appear as yellow. However it is reasonable to accept that 'red' and 'yellow' mean 'light of wavelengths between 620–750nm' and 'light of wavelength between 570–590 nm' respectively.

We have also seen that discovering what the mental processes behind such phenomena of the visual system as gross colour naming is far from straightforward or lacking in controversy. We noted that Berlin and Kay's theory is based on two notions, that of Hering's theory, and the importance of language. We saw that both the centrality of Hering's theory in understanding perception, and even its truth, has been disputed. We have also seen that the importance of language in perception has also been disputed, with cross-cultural psychologists suggesting that language might be important primarily in communication. We can thus conclude that this aspect of the 'beholder's share', or the nativist's side, requires an understanding of culture; something we will examine in more depth in *Chapter 3*.

What does all this tell us about perception in general? We might say that we can indeed detect the properties of objects, which include the seemingly less solid properties such as colour. We might most importantly say that we do, however, need to investigate the properties of what Gombrich called 'the beholder's share', thus leaving us with the conclusion that in order to study art we must study visual perception.

CONCLUSION

In general, we can draw the following conclusions from this chapter. The first section, 'Resemblance and the Debate about Depiction' (p. 66), showed that for our purposes here the word 'resemblance' was more appropriate than realism, though we will show in *Chapter 2* (p. 161) that the word resemblance itself has its limitations. The second section, 'Against Simple Resemblance: Saccades, Screen Colours, Screen Resolution, and the Cornsweet Illusion (Application of Psychology to Art 1)' (p. 81), examined and refuted one of the main theories from art history that the visual system, in this case the retina, distorts the information about a subject, causing us to view the world in a distorted way. However, the observation that a mixture of red light and green light combined appears to us the same as yellow light, casts some doubt on the reliability of the visual system.

We saw our understanding of depiction develop from the idea that a picture sends the same array of light through the pupil as would the subject matter itself, to the idea that a picture documents the path of light and subsequent nerve signals as they pass from the subject matter (as light) through whatever is in-between the subject matter and the viewer (e.g. air, glass, etc.) and through the visual system (as electrical signals).

The third section, 'Distortion Beyond the Primary Visual System: The Multiple Spotlights' (p. 97), and the fourth section, 'The Reliability of the Visual System' (p. 109), examined why, despite the visual system's inherent flaws, we can generally trust our eyes, while remembering that misrecognition and distortion remain possibilities.

We might note that we still have two issues to deal with. Firstly, I mentioned that the word 'resemblance', while better for our purposes that 'realism', is still somewhat deficient; though we have not yet examined what this deficiency is. Secondly, there is the fact that many pictures, from those of Picasso to Northern European rock engravings, while resembling their subject matter to some extent, deviate from it a great deal. *Chapter 2* (p. 161) will examine the problems of the word 'resemblance', and *Chapter 3* (p. 208) will examine the issue of pictures deviating from reality.

CHAPTER 2. INFORMATIVENESS: GOING BEYOND SIMPLE RESEMBLANCE

RECOGNITION-BY-COMPONENTS

INTRODUCTION

This second chapter examines further the problems with the idea of ‘resemblance’. The issue can be summed up in the somewhat facetious writings of French writer Alphonse Allais (1854–1905). Allais proposed a number of hypothetical paintings, including *First Communion of Anaemic Young Girls in the Snow,* and *Tomato Harvesting by Apoplectic Cardinals on the Shore of the Red Sea.* The seeming anti-clericism of Allais does not concern us here; what does is the fact that such paintings would be unsuccessful as pictures.

Let us examine this further with two more unsuccessful pictures:

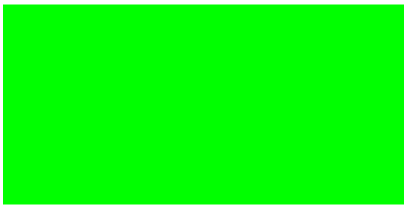

Figure 45 ***Frog on a Snooker Table Seen from Above.*** **By the author.**

Figure 46 ***Train on a Moonless Night in a Power Cut.*** **By the author.**

Both of these pictures are fine with respect to the understanding of art that we developed in *Chapter 1* (p. 65), namely that a picture documents the path of light and subsequent nerve signals as they pass from the subject matter (as light), through whatever is in-between the subject matter and the viewer (e.g. air, glass, etc.), and through the visual system (as electrical signals).

However, *Frog on a Snooker Table Seen from Above* and *Train on a Moonless Night in a Power Cut* are hardly successful as pictures. In this chapter we will examine why this is, by considering the notion of the *informativeness* of a picture. We will develop a new theory of depiction that states that a picture resembles visual features of its subject matter, though it may leave out certain of these features, while modifying or distorting others. The features chosen by the artist provides the information about the subject matter that the artist feels is relevant. These modifications and distortions either aid the presentation, or distort the subject matter.

The chapter is divided into three sections. ‘Recognition-by-Components’ (p. 162) examines a theory of recognition based on ideas from the psychological theory of geons. ‘Informativeness’ (p. 185) examines Dominic Lopes’s version of the theory of informativeness, namely the idea of aspect recognition, and how this can be applied to the understanding vertices. Finally, ‘Resemblance and Informativeness’ (p. 196) marries the idea of aspect recognition with the notion of resemblance.

RECOGNITION-BY-COMPONENTS (APPLICATION OF PSYCHOLOGY TO ART 4)

INTRODUCTION

Consider for a moment Figure 47 (p. 163) and Figure 48 (p. 164), Leonardo da Vinci and Andrea del Verrocchio’s *Annunciation*. Most people will take it for granted that, due to the physical properties and geometry of the eye, linear perspective provides the most lifelike way to depict a scene in three-dimensional space. In this painting, however, despite the linear perspective being perfectly composed, the Virgin's book appears curiously two-dimensional. If we now turn to Figure 49 (p. 164), Giotto's *Meeting at the Golden Gate*, we see that the linear perspective is badly composed. The horizontal lines at the top of the two towers do not line up, and the rusticated blocks at the bottom of the towers do not recede into space. Despite these failings, however, the buildings in the Giotto have a solid three-dimensionality, unlike the Virgin's book in the Leonardo/Verrocchio. We are thus left with a conundrum: how can the correct construction of the Virgin's book created using linear perspective fail to provide a life-like three-dimensionality, whereas the depictions of buildings constructed with Giotto's poor perspective succeed?

Figure 47 Leonardo da Vinci and Andrea del Verrocchio. *Annunciation.* c.1472–1475.

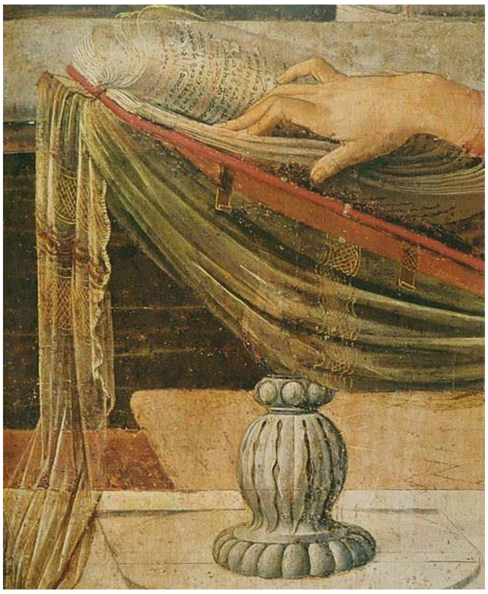

Figure 48 Leonardo da Vinci and Andrea del Verrocchio. *Annunciation.* c.1472–1475. (Detail.)

Figure 49 Giotto di Bondone. *Meeting at the Golden Gate.* c.1305.

We will see that in the answer to this question also lies the answer to our problem of *Frog on a Snooker Table Seen from Above* and *Train on a Moonless Night in a Power Cut* not being very successful pictures. We will see that the informativeness of a picture is another concept that needs to be added to resemblance in any theory of depiction, and that visual psychology, including the idea of recognition-by-components, can help us to develop such theories.

The section is divided into three subsections. 'Recognition-by-Components' (p. 165) describes the theory of recognition-by-components, and in particular the notion of the three vertices, T, Y, and arrow, and their role in recognition. 'Example 1—Hieronymus Bosch' (p. 169) examines an application of this theory to the depiction of space in the work of painter Hieronymus Bosch. Finally, 'Example 2—Wölfflin' (p. 175) uses recognition-by-components to explain and extend art historian Wölfflin's theories of the Classical and Baroque.

RECOGNITION-BY-COMPONENTS

In order to solve the problem of the Virgin's book we will use the cognitive theory of recognition-by-components, which was proposed by psychologist Irving Biederman. Biederman argues that we recognise objects by mentally decomposing them into simple three-dimensional shapes, such as cones, cubes and spheres, shapes that Biederman calls 'geons'. Biederman argues that there are a limited number of these geons, perhaps 30 to 40. Geons have properties such as round-headedness or pointed-headedness, and are prismatic or contracting; they thus consist of a wide range of shapes, including wedges and cylinders. Geons can describe a great number of figures; for example, a sphere on a cone can describe an ice-cream; a sphere with one big cylinder and eight smaller cylinders can describe a human; a flat cuboid on top of a squatter cuboid with a wedge in front and a hemisphere to one side can describe a desktop computer. That geons are simple shapes makes them easily and thus quickly recognisable; that there are a small number of geons makes for easy and thus quick recognition; and that a great number of shapes can be made from geons makes it possible for humans to recognise a great number of different forms. As a result of this, recognition-by-components theory has been used to explain our ability to recognise complex shapes quickly (Biederman, 1987, p. 135).

What makes recognition-by-components theory powerful is firstly that it delineates a mechanism that explains why we are able to recognise complex shapes quickly, but secondly because it is viewpoint-invariant. Attempts to simplify three-dimensional figures into two-dimensional shapes would result in even simple three-dimensional figures requiring complex analysis by the visual system to achieve recognition, something difficult to reconcile with our ability to recognise large numbers of three-dimensional shapes very quickly. The occlusion shape of a simple cuboid, for example, can look like one of three different rectangles or squares when a side is looked at face on, and a number of different squares, rectangles and irregular hexagons when looked at from various oblique angles. It thus becomes necessary to hypothesise a mechanism by which we can recognise simple three-dimensional shapes regardless of viewpoint, which would in turn facilitate the decomposition of complex objects into simpler objects and thus facilitate object recognition.

The aspect of recognition-by-components theory that is of interest here is Biederman's theory that the recognition of geons is facilitated by the vertices of objects. Depictions of objects where the vertices are clearly depicted are more easily recognised than objects where only the edges are depicted. In Figure 50 (p. 167), for example, we can see that the objects of the left-most column are more easily recognised in the middle column than in the right-most column.

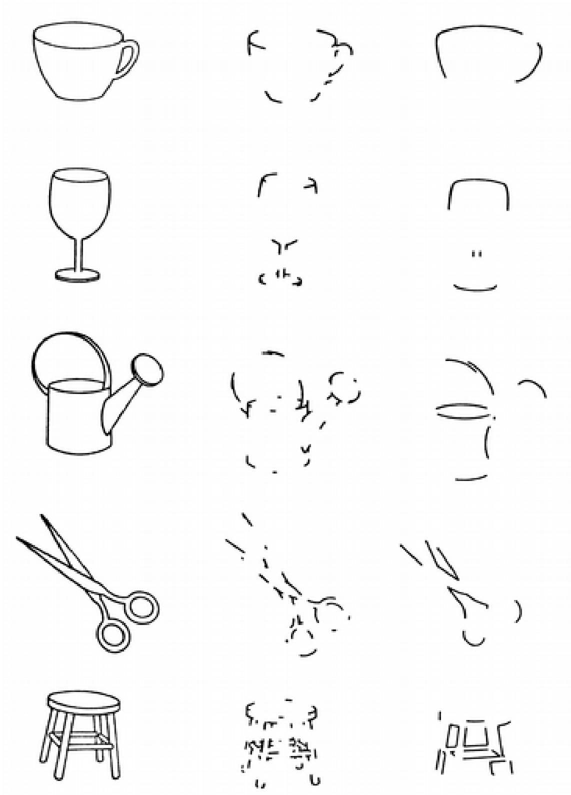

Figure 50 Drawing of objects with sections left out, to illustrate recognition-by-components theory (Biederman, 1987, p. 135).

Biederman classifies vertices into three types: the arrow-vertex (the vertex on an external edge of an object), the Y-vertex (the vertex on an internal edge of an object), and the T-vertex (the vertex that appears in segmentation and occlusion) (Figure 51, p. 168). By the recognition of vertices, the viewer gains information about the shape of objects, and whether or not an object is in front or behind any other object.

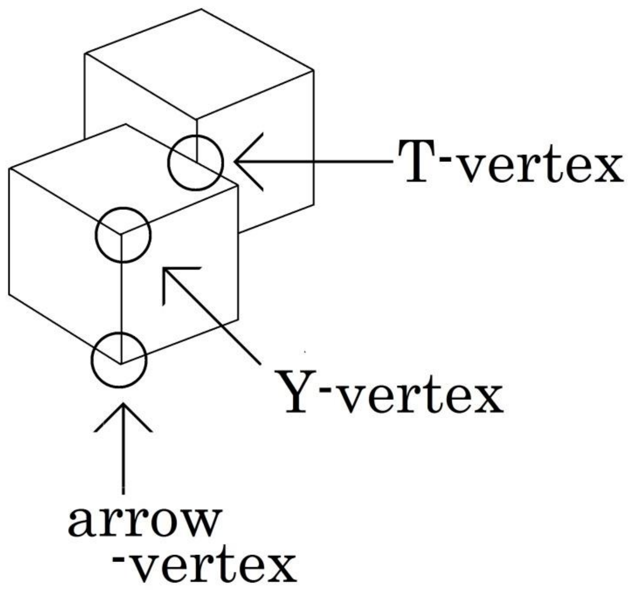

Figure 51 Biederman's three vertices. Diagram by the author.

Support for the notion of vertices from recognition-by-components theory can be found in experiments performed by Biederman using line drawings such as those in Figure 50 (p. 167). Biederman presented these degraded line drawings to observers and discovered that they recognised objects much quicker in the middle drawings where the vertices are present than the right-most drawings where the vertices are absent (Biederman, 1987, p. 87).

One key assumption of recognition-by-components theory is that the eye is automatically drawn towards these vertices, rather than to straight lines. This implies that much of human visual processing involves looking for intersections of lines and interpreting them.

We might thus note three features of Biederman's theory. Firstly, an object can be recognised from a number of viewpoints, making it *viewpoint invariant*; secondly, a large number of different types of object can be recognised using the same basic features, known as geons; thirdly, a volumetric form, such as one of Giotto's buildings, might not be accurate according to linear perspective, but if the vertices are in the right relative positions the viewer will identify a volumetric form, giving recognition a degree of elasticity.

EXAMPLE 1—HIERONYMUS BOSCH

An example of how recognition-by-components theory can be applied to the study of painting involves one of the early paintings of Hieronymus Bosch (c.1450–1516), *Adoration of the Magi* (Figure 52, p. 171). The technique of the cut-away depiction of the building, used to show the activity within, is successful in its role of aiding the narrative, but is less successful in its depiction of volumetric form (Bosing, 1994, p. 20). The notion of the vertex from recognition-by-components theory can explain this lack of success.

As we have seen in Figure 51 (p. 168), one way that vertices can indicate space is by occlusion. Occlusion occurs when one object partially obscures another object, thus showing that the first object is in front of the second object. Recognition-by-components theory posits that occlusion is indicated by a T-vertex. We should note that there is only weak occlusion in the Bosch painting, as the 'overpainting' of Figure 53 (p. 171) demonstrates. Figure 53 (p. 171) reinserts the central support of the building, which the artist left out in order to help form the 'cutaway' theme. We can observe that the changes made in Figure 53 (p. 171) make the painting look more three-dimensional, by increasing the number of T-vertices. There are many of these vertices in the overpainted picture, including one made with the central support and St Joseph's arm, one made with the central support and the arm of the green-robed Magi, and a number made with the central support and the folds of the Virgin's robe.

The overpainted picture now looks more three-dimensional, but its three-dimensionality is still weak. The only information occlusion provides is that an object in front or behind another; it does not properly depict volumetric form. The vertices that describe volumetric form are the arrow and the Y, and thus in order to depict volumetric form an artist should use one of these.

How has Bosch failed to include one of the other vertices? We might note that the vertex at the bottom of the gable nearest to the picture plane should be an arrow-vertex, thus providing a depiction of volumetric form. However, this is not the case. The bottom edge of the gable and the bottom edge of the thatch instead meet together to form a straight line, thus leaving the corner of the roof without a defining arrow-vertex. We should note that in fact the two lines discussed do not quite make a straight line. However, that we would perceive the two lower edges of the roof as one line, rather than two non-parallel lines, can be demonstrated by an optical phenomenon known as the 'hypotenuse illusion', which we see illustrated in Figure 54 (p. 172). The shape in Figure 54 (p. 172) looks like a right-angled triangle, but in fact its hypotenuse is made up of two separate non-parallel lines; the shape is in fact four-sided.

In a similar way we can say that we perceive the bottom edge of the roof as one straight line. We can thus argue that the vertex at the bottom of the gable is not best described as an arrow-vertex, lacking as it does the necessary clear angle of an arrow-vertex. This is further demonstrated by Figure 55 (p. 172), where the top picture shows the roof uncorrected, and the bottom picture shows the vertex overpainted as a clear arrow-vertex. Figure 56 (p. 172) shows in full how the use of a clear arrow-vertex improves the three-volumetric form of the painting.

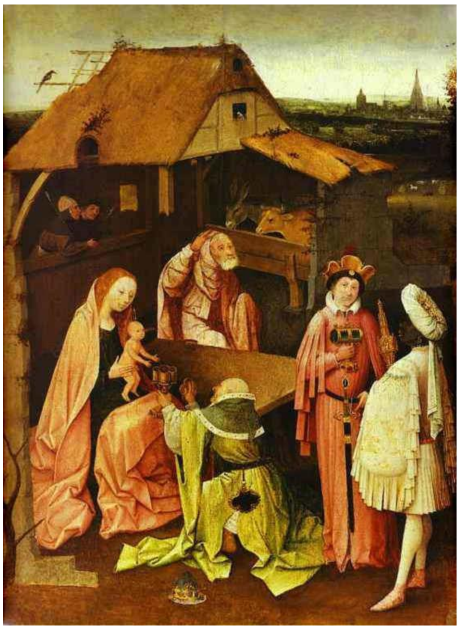

Figure 52 Hieronymus Bosch. *Adoration of the Magi.* c.1500–1550.

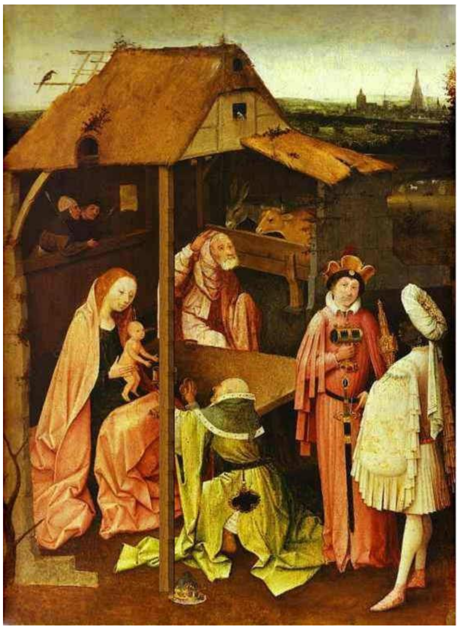

Figure 53 Hieronymus Bosch. *Adoration of the Magi.* c.1500–1550. Additions by the author.

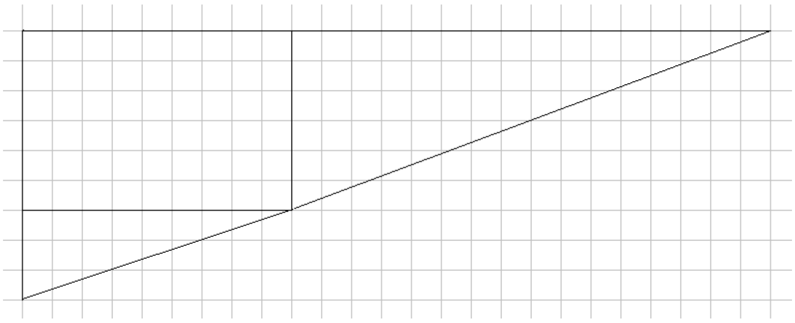

Figure 54 Hypotenuse illusion. Diagram by the author.

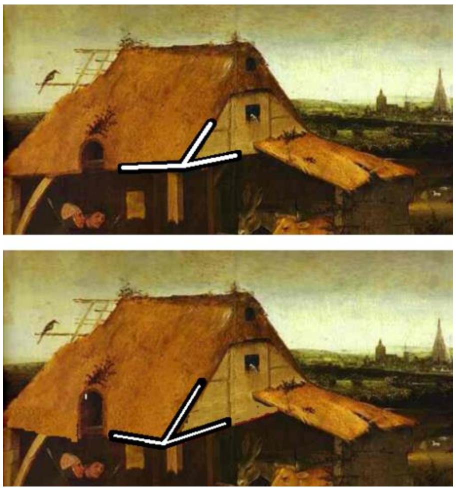

Figure 55 Hieronymus Bosch. *Adoration of the Magi.* c.1500–1550. (Detail.) Additions by the author.

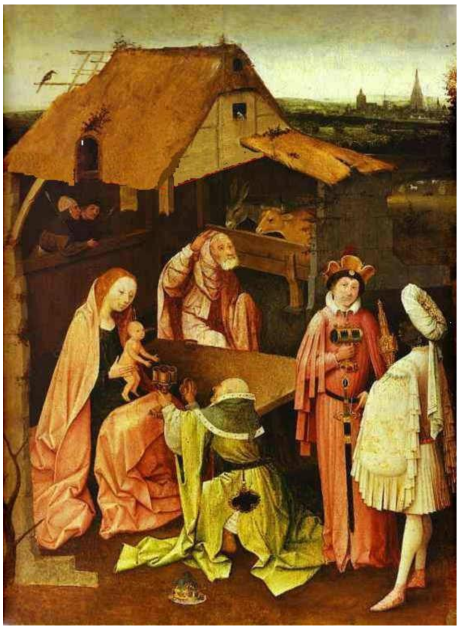

Figure 56 Hieronymus Bosch. *Adoration of the Magi.* c.1500–1550. Additions by the author.

We can now return to Leonardo da Vinci and Andrea del Verrocchio's *Annunciation* and Giotto's *Meeting at the Golden Gate*, and the problem of how the correct construction of the Virgin's book created using linear perspective fails to provide a life-like three-dimensionality, whereas the depictions of buildings constructed with Giotto's poor perspective succeeds.

Recognition-by-components theory provides an explanation for this, illustrated in Figure 57 (p. 173). The depiction of the book is similar to Bosch's roof by being constructed predominately using one straight line. It fails to produce a clear vertex, thus explaining why the three-dimensionality of the book is weak. Figure 58 (p. 174) shows the range of vertices in the entire bookstand, demonstrating how the depiction of the base is highly volumetric, while the top on which the book actually rests is not. If we now turn to Giotto's *Meeting at the Golden Gate* (Figure 59, p. 174), we notice that the towers have a range of all three types of vertices, hence facilitating a strong depiction of volumetric form.

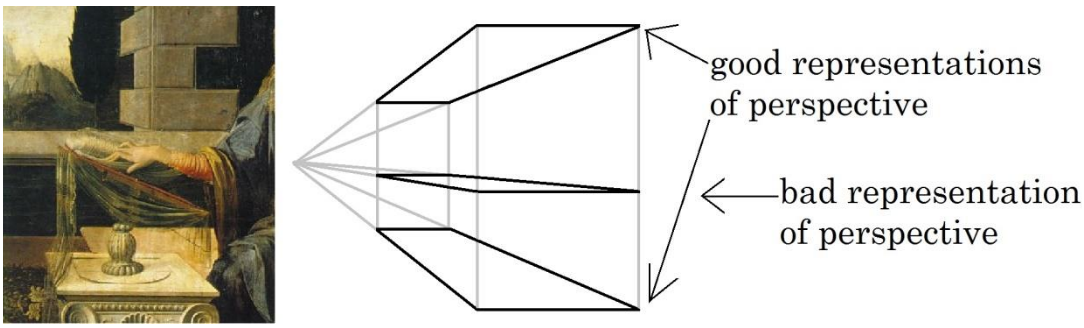

Figure 57 Leonardo da Vinci and Andrea del Verrocchio. *Annunciation.* c.1472–1475. Detail, with a diagram describing the representation of space. Diagram by the author.

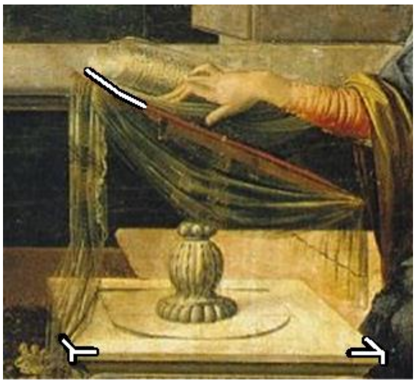

Figure 58 Leonardo da Vinci and Andrea del Verrocchio. *Annunciation.* c.1472–1475. Detail, with vertices added. Additions by the author.

Figure 59 Giotto di Bondone. *Meeting at the Golden Gate.* c.1305. Vertices added. Additions by the author.

The psychological theory of recognition-by-components adds to our understanding of the depiction of three-dimensional space in a substantial way. Linear perspective is not in itself enough to produce lifelike three-dimensional depictions: volumetric form is required, something facilitated by the inclusion of vertices by artists in pictures.

EXAMPLE 2—WÖLFFLIN

The second application of the theory of recognition-by-components to art concerns the work of art historian Heinrich Wölfflin. Wölfflin is known mainly for his 1915 book *Principles of Art History*, but the *Principles* was preceded by other substantial works, in which his interests varied. Wölfflin's psychologistic approach of examining the 'eye', or visual perception, makes him of interest here. Wölfflin's first theoretical position was with a simple empathy theory, of a type common at the time, in which there is an identification by the viewer between his or her own body and an artwork. Wölfflin later developed the more sophisticated notion of the sense of architectural fiction. For example, if one architectural structure is supported by a second, the architect might give the second structure the appearance of being crushed by the first structure, to fictitiously augment and delineate the second structure's architectural role. Wölfflin then moved on to a formalist exposition of the development of Classic Art in the Renaissance, which led on to his final position, that of the 'purely visual' basis of artwork of the *Principles* (Podro, 1982, pp. 98–101). Hence Wölfflin developed his opinions over time, though not all writers have seen this development as a process of improvement (Gombrich, 1960, p. 14). Wölfflin's early notions of empathy and fiction are interesting in terms of psychology, but he did not develop them into a mature theory, instead passing over them to work on the *Principles*.

The *Principles* is an attempt to understand style. Wölfflin argued there are four main causes of style: the individual, the period, nationality, and the specifically visual facets that are the book's focus (Wölfflin, 1915, 1950, pp. 1–13). He considered not only depiction, but also architecture and ornament; style being 'a schema which … is far more deeply rooted than in mere questions of the progress of imitation. It conditions the architectural work as well as the work of representative art' (Wölfflin, 1915, 1950, p. 13). He also argued for the importance of colour, though this is often neglected in discussions of Wölfflin, despite each of the five sections of the book containing examples (Wölfflin, 1915, 1950, pp. 51, 82–83, 127, 130–131, 164–165, 203).

Wölfflin's argument about the specifically visual can be summarised thus. There is a cyclical historical process in which visual culture develops, an alternation of what Wölfflin terms Classical and Baroque. The terms Classical and Baroque can be described by five opposing pairs of contrasts: linear and painterly, plane and recession, closed and open, multiplicity and unity, absolute clarity and relative clarity, where the first is Classical and the second is Baroque (Wölfflin, 1915, 1950, pp. 14–17).

Wölfflin outlines his book with copious examples, including drawings, paintings, sculpture and architecture, together with detailed analyses of their 'Classical' and 'Baroque' features. A chapter is devoted to each pair of concepts. The table below illustrates the comprehensive and exhaustive nature of Wölfflin's systematic descriptions:

Table 6 Wölfflin's applications of his Classical/Baroque distinctions

Concepts (Classical /Baroque)	Examples		
	Figurative art	**Colour**	**Decorative and Architectural**
Linear /Painterly	Edges continuous in drawing /Edges broken in drawing (32–33)	Shadows made by adding black /Shadows incorporate complementary colours (51)	'Solid, enduring, concrete form' /A rococo staircase forces us to 'surrender to changing views' (64)
Plane /Recession	Figures posed in a plane parallel to the picture plane, implying relief /Receding diagonal movement between figures (76–77)	Colour perspective arranged in defined strata (Patenir) /Strata small (Brueghel) (82–83)	Rectangular cupboard with a self-contained front, such that the front's shape is still clear in foreshortened side view /Such a cupboard with bevelling, so that the front's shape is not clear from the side (119–120)
Closed (Tectonic) /Open (A-Tectonic)	Elements arranged around a clear mesh of horizontals and verticals /Diagonals intersecting the mesh, figures not aligning with the architecture of the scene (124–128)	Pure oppositions of colour (balance by contrasts) /Single colour in excentric position dominating (127, 130–131)	There is a certain necessity of tectonic form in architecture; straight lines and right angles are natural to it /Bernini's 'sprinkled' bees over the Urban tomb, breaks up this necessity (149–151)
Multiplicity /Unity	A figure is satisfactory in itself /Each figure needs to be seen in relation to the others in the picture (156–157)	Multiple colours balanced against the whole /Single colour dominates (164–165)	Each part of a building is clearly articulated /Parts merged together (e.g. floors by pilasters) (186–187)
Absolute Clarity /Relative Clarity	Silhouettes defined /Silhouettes' outline undefined (196–197)	Colour articulates an object's form /Colour independent (203)	Classical room has clear boundaries /Rococo mirror halls blur the room's clarity (223)

(Numbers in brackets refer to (Wölfflin, 1915, 1950))

It is Wölfflin's second pair of concepts that are of interest here, the difference between Classical and Baroque styles concerning depth in art:

> Classic art reduces the parts of a total form to a sequence of planes, the baroque emphasises depth. Plane is the element of line, extension in one plane the form of the greatest explicitness: with the discounting of the contour comes the discounting of the plane, and the eye relates objects essentially in the direction of forwards and backwards.

(Wölfflin, 1915, 1950, p. 15)

We have seen that there are two constituents of the linear depiction of depth: linear perspective, and the vertices described by recognition-by-components theory. We will examine in turn how each of these constituents relates to Wölfflin's second pair of concepts.

Wölfflin dealt with linear perspective explicitly. Classical, or planar, form refers to lines parallel to the picture plane, whereas Baroque, or recessive, form refers to those lines not parallel to the picture plane, which appear diagonal. Gaiger defines this precisely:

> Whereas the planimetric involves a careful co-ordination of parts across the picture surface, the recessional employs movement into depth, obliging the spectator to co-relate background and foreground. This is achieved through the use of diagonals or the emphatic employment of perspective.

(Gaiger, 2002, p. 29)

We might analyse this further by examining Wölfflin's analysis of two paintings of Adam and Eve, a 'Classical' painting by Palma Vecchio, and a 'Baroque' painting by Tintoretto. Vecchio places the figures in a plane parallel to the picture surface, while Tintoretto places the figures in a diagonal line. Wölfflin writes about the Tintoretto:

> The model is placed far back in the room, but lives only in relation to the man for whom she poses, and thus, from the outset, a vigorous into-the-picture movement comes into the scene, materially supported by the lighting and the perspective.

(Wölfflin, 1915, 1950, p. 77)

The first observation we take from the above is the notion of *relations* between objects in Baroque pictures. According to Wölfflin, Classical pictures emphasise the independence of objects, while Baroque pictures emphasise the relations between objects. The second observation we take from the above is that it is the *diagonal* lines of the picture plane that facilitate these depicted spatial relationships; it is the diagonals that join objects in different planes of a picture together.

To illustrate this further consider Figure 60 (p. 180). The left hand side of this figure is constructed in Wölfflin's Classical way, while the right hand side is constructed in Wölfflin's Baroque way. If we now turn to Figure 61 (p. 180), the colour-coding shows how the diagram's Classical side has only lines parallel to the picture plane, while the Baroque side has a mixture of lines parallel and non-parallel to the picture plane.

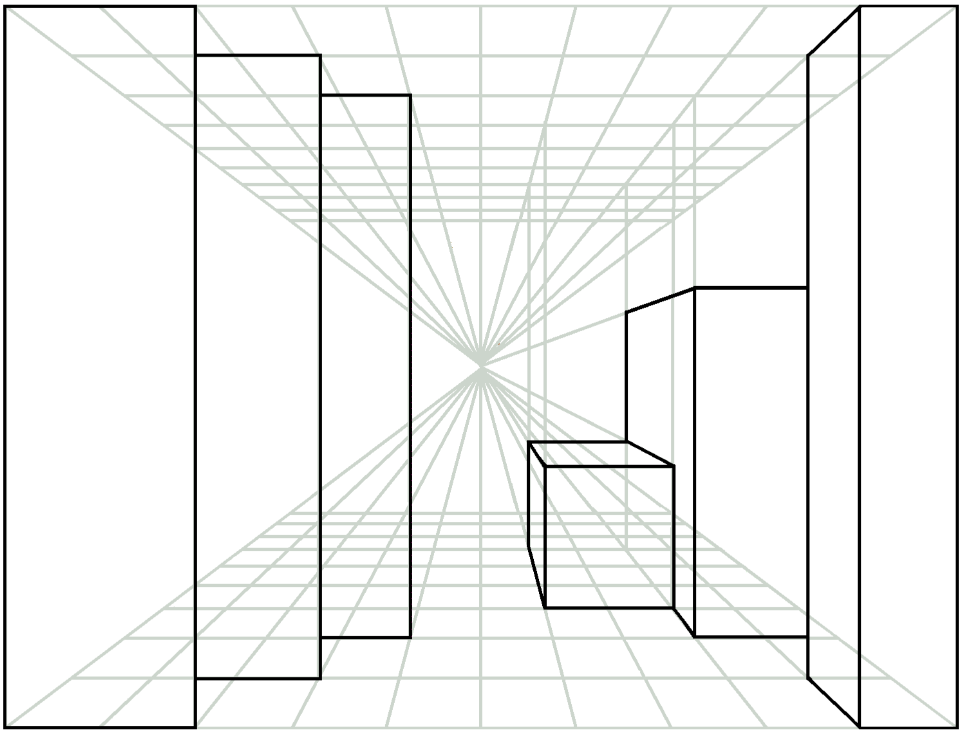

Figure 60 **Diagram showing planimetric objects (left) and recessional objects (right). Diagram by the author.**

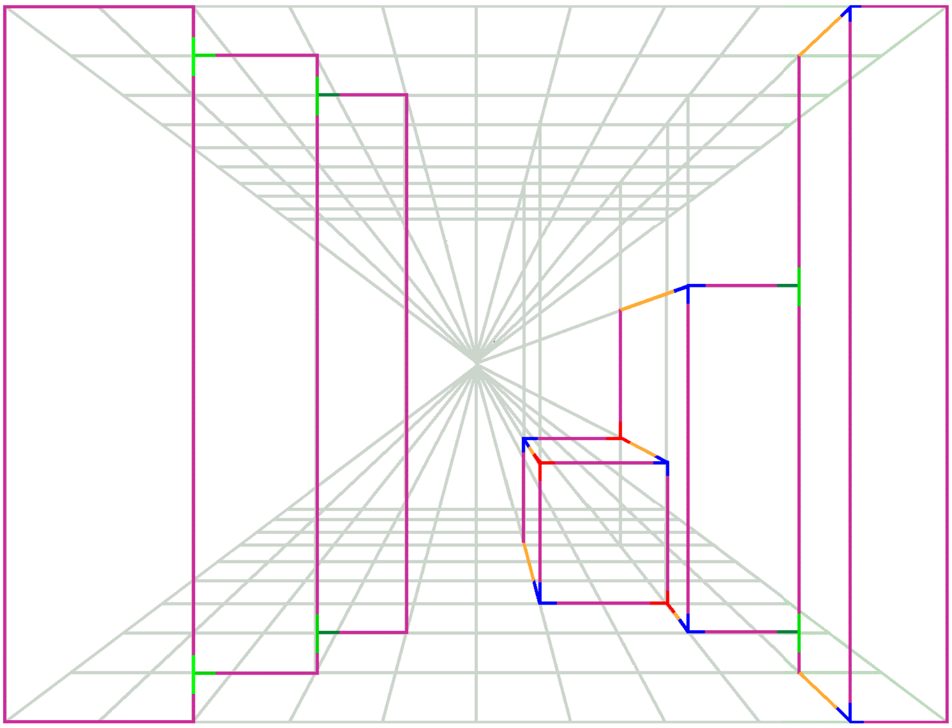

Figure 61 **Above diagram with colour indication. Purple: parallel to the picture plane. Red: Y-vertices. Amber: not parallel to the picture plane. Blue: arrow-vertices. Green: T-vertices. Diagram by the author.**

Linear perspective was described long before Wölfflin, and as a result he was able to incorporate it into his theory. The vertices described by recognition-by-components were only theorised about after Wölfflin, so we will have to derive the relationship ourselves. If we again consider Figure 61 (p. 180) we see that the Classical side contains only T-vertices, shown in green, while the Baroque side adds to this Y- and arrow-vertices, shown in red and blue respectively. The reason for this can be seen by analysing the vertices themselves. The Y- and arrow-vertices each have at least one line that appears recessional to the viewer, the defining feature of depth in Wölfflin's scheme. The T-vertices are planimetric as they have no lines that appear recessional to the viewer. As a result we can say that in Wölfflin's scheme Y- and arrow-vertices are Baroque, while a Classical picture will have only T-vertices, making T-vertices a defining feature of Wölfflin's Classicism.

Wölfflin's ideas have been controversial in many respects, but nevertheless they provide a penetrating description of art in the Renaissance and Baroque periods. How might the theory of recognition-by-components further Wölfflin's description? Though linear perspective describes an important aspect of art, we have seen above with the Leonardo/Verrocchio that it fails to account for all the properties of volumetric form. The most telling example of this relates to architecture. Wölfflin wrote:

> The erection of the obelisk in the square in front of St. Peter's in Rome is also a baroque arrangement. Certainly it primarily fixes the middle of the square, but it also takes account of the axis of the church. Now we can imagine that the needle simply remains invisible if it coincides with the middle of the church façade; that proves that this view was simply no longer regarded as a normal one. But more forcible is the following consideration: according to Bernini's plan the entrance part of the

> colonnade, now open, should also have been closed in, at least partially, by a central portion which would have left broad approaches open on both sides. But these approaches are, or course, laid out obliquely to the church façade, that is, the first view was of necessity a side view.

(Wölfflin, 1915, 1950, p. 119)

Wölfflin thus argues that Bernini designed the square in front of St Peter's façade to encourage viewers to walk to the side of the square and thus view the façade from an oblique angle. Such views allow the volumetric form of the façade to be clearly seen. The side view forces the viewer to see Y- and arrow-vertices in the façade, which recognition-by-components theory tells us facilitates the recognition of volumetric form. Recognition-by-components theory thus provides a description of an important feature of the Baroque.

We now need to ask the question of how this relates to pictures. Volumetric form as described by recognition-by-components tends to appear mainly in the form of artificial objects such as buildings and furniture. An important object of this type with potential for strongly depicted volumetric form in Renaissance and Baroque art is the cross of Jesus. Wölfflin notably wrote about scenes surrounding the crucifixion:

> The baroque antithesis to Raphael and Dürer is here represented by Rubens' Christ Bearing the Cross (engraving by Pontius with a variant anterior to the picture in Brussels). The recessional movement most brilliantly developed, and made still more interesting by an upward movement. The stylistically new factor we are looking for certainly does not lie in the merely material motive of the direction of movement, but, as it is a question of a principle of presentment, in the way in which the theme is handled, how every recessional element is

> brought out for the eye and, on the other hand, how everything which could emphasise the plane is repressed.
>
> (Wölfflin, 1915, 1950, p. 94)

Following our combination of the *Principles* of Wölfflin and the recognition-by-components theory of Biederman, we would expect Poussin and Raphael generally to supress arrow- and Y- vertices, and Rubens and Rembrandt to make extensive use of them, when painting regular cuboidal forms such as the cross. An example of this of can be seen by contrasting the clear Y- and arrow- vertices of the cross in Rembrandt Harmenszoon van Rijn's 1633 *The Descent from the Cross* with the lack of vertices in Rogier van der Weyden's 1435 *The Descent from the Cross*. Rembrandt's unusual angle for the cross displays the vertices clearly on the cross-beam, creating a strong volumetric form, while the lack of volumetric form in van der Weyden's painting is caused by the lack of clear Y- and arrow-vertices.

CONCLUSION

We can thus conclude that recognition-by-components provides us with an understanding of the depiction of volumetric form where traditional theories of linear perspective have failed. We have seen the resultant explanations for the deficiencies of a number of paintings, including those by Leonardo and Verrocchio, and Bosch, as well as an explanation of the surprising success of paintings such as Giotto's *Meeting at the Golden Gate*.

Visual psychology can also be said to bring new insights into the work of Wölfflin. Recognition-by-components explains that, following Wölfflin's scheme, Classical art emphasises the T-vertices, while Baroque emphasises the arrow- and Y- vertices. This gives a greater precision to Wölfflin's ideas, and situates them in a framework of experimental psychology. This facilitates Wölfflin's project of creating a 'psychology of form', to place psychology in history, and make visual history 'psychologically intelligible' with new depth (Wölfflin, 1915, 1950, pp. 9, 229).

We should note that the delineation of borders is not the only way of depicting volumetric form, shading being an obvious alternative. For example, in the Leonardo (Figure 52, p. 171) the lack of differentiation in tone between the face and the edges of the pages at the top of the book is another way that contributes to the weak volumetric form of the top of the bookstand. In the Bosch (Figure 48, p.164), the relative darkness of the gable in the unamended Bosch is the main way of providing volumetric form for the roof, and Bosch has some success with it. However, the addition of the T-vertex greatly enhances the volumetric form, indicating that linear differentiation of form is an important, though as in the case of a tonally-described sphere, not necessarily vital way of depicting volumetric form.

The most important result of our examination of vertices to us here is, however, the idea that the depiction of vertices provides useful *information* that linear perspective does not in itself provide. Just as *Train on a Moonless Night in a Power Cut* provides the viewer with no information about the location of the train relative to the picture surface (or anything else for that matter), so Leonardo's bookstand presents the viewer with little information about its volumetric form. We can thus note that informativeness is a crucial feature of depiction. The following section will examine this feature further.

INFORMATIVENESS

The main theory of informativeness we will examine is one of the most developed of such theories, that of Dominic Lopes. Though I will largely accept Lopes's theory, I will argue that we should add resemblance to it. I will argue that resemblance is one of the defining features of depiction, and that resemblance and informativeness together make for a better overall understanding of depiction.

The problem however, as noted earlier, is that Lopes is an opponent of resemblance theories, so it will be necessary to analyse Lopes's arguments in detail so that resemblance and the sophisticated development of informativeness created by Lopes can be reconciled.

Lopes notes two features of depiction that need to be explained. As noted earlier, these two questions date back (at least as far as the current debate is concerned) to Gombrich's *Art and Illusion*, namely the need to explain the phenomenon of pictorial diversity itself, and the need to understand precisely how and why cultures have different ways of depicting and why they change over time. As Lopes puts it:

> But while artists have always claimed to copy what they see, the pictures of different cultures and different eras represent the world in strikingly different ways. Egyptian tomb paintings, medieval miniatures, ukiyo-e prints, north-west coast First Nation totems, the cows and horses at Lascaux, the collages of Picasso and Braque, all illustrate not only the diversity but also the cultural embeddedness and historical development of depiction. Hence Gombrich's problem: how can depiction have historical and cultural dimensions if pictures are perceptual and perception is ahistorical and universal across cultures?

(Lopes, 2004, pp. 8–9)

Lopes notes Gombrich's proposed solution to these problems. Firstly, Gombrich's overall explanation of depiction is that artists attempt to reproduce the experience of seeing the objects depicted: namely, an 'illusion' of visual experience. Secondly, Gombrich explains different cultures having different pictorial systems by the notion that elements of pictures may be conventional, for example the colour brown being used to depict green grass.

Gombrich might have been somewhat of two minds with this view that he is a proponent of a type of conventionalism. Consider this footnote from the preface to the 2000 edition of *Art and Illusion*:

> 1 See Nelson Goodman, Languages of Art: An Approach to a Theory of Symbols, Indianapolis, 1968 (I may here mention that the late author allowed me to quote a letter that he wrote to me dissociating his own views from those of the extremists:- see The Image and the Eye, Oxford, 1982, p.284); also Norman Bryson, Vision and Painting, the Logic of the Gaze, Macmillan (London), 1983. For the history of this approach, see my article Voir la Nature, Voir les Peintres in Les Cahiers du Musée national d'art moderne, vol.24, Été 1988, Art de Voir, Art de décrire II, pp. 21-43.

(Gombrich, 2000)

Thus Gombrich believed even Goodman would distance himself from the extremes of conventionalism. I shall examine this in more depth later, but for the moment we might note there is an element of conventionalism in Gombrich's work.

We also noted earlier that the history of depiction theory after Gombrich involves four schools of thought: resemblance, experiential, conventional, and perceptual. As Lopes noted, resemblance is an ancient theory, while as we saw above Gombrich played a part in introducing the other three: experiential, conventional, and perceptual. Lopes largely rejects the resemblance and experiential, while taking elements of the conventional and adding it to the perceptual.

Lopes argues that Gombrich's mixture of illusion and convention fails to explain pictorial diversity. He says:

> On the one hand, Gombrich maintains a monolithic conception of an ideal match between pictures and objects. This means that artists interested in enhancing pictures' perceptual aspect have their goal set out for them: the route of the march towards a better match is predetermined …
>
> On the other hand, if the adoption of a schema in a context is a matter of convention, then choices of schemata are arbitrary, for conventions are arbitrary.

(Lopes, 2004, p. 10)

Lopes thus argues for a new approach, based on recognition, though incorporating the ideas of systems from conventionalism. In this thesis we will be re-introducing resemblance to Lopes's recognition theory, somewhat against Lopes's own opinions. As a result we will begin by examining conventionalism in order to find those parts Lopes uses and why he rejects others, we will then move on to Lopes's recognition theory, and we will finally move on to re-introduce resemblance.

Gombrich might be said to have brought conventionalist theories to the table, but it was philosopher Nelson Goodman who developed them far beyond Gombrich's original intentions. We will begin by examining Goodman's ideas, and then examine what Lopes agrees with and what he rejects. Lopes's opposition to Goodman's conventionalism does not involve resemblance, but there is a resemblance theory objection, which I will return to at the end.

Nelson Goodman maintained that pictures are composed of arbitrary symbols. He argued this point in detail in relation to linear perspective in his 1968 book *Languages of Art*. Though Goodman used linear perspective as his example, we will see that it is readily extended to vertices. Goodman's theory of notation and depiction was structured around the idea that both are based on symbols, rather than resemblance. Notably for the issue here, namely the depiction of space, Goodman argued that perspective drawing is a symbolic system, not something that mimics the array of light entering the eye as we developed above. Goodman writes:

> So far, I have been playing along with the idea that pictorial perspective obeys laws of geometrical optics, and that a picture drawn according to the standard pictorial rules will, under the very abnormal conditions outlined above, deliver a bundle of light rays matching that delivered by the scene portrayed. Only this assumption gives any plausibility at all to the argument from perspective, but the assumption is plainly false.

(Goodman, 1968, pp. 15–16)

Goodman also asks:

> What can the matching of light rays delivered under conditions that make normal vision impossible have to do with fidelity of representation?

(Goodman, 1968, p. 13)

In order to explain his argument, Goodman asks us to consider Figure 62 (p. 189).

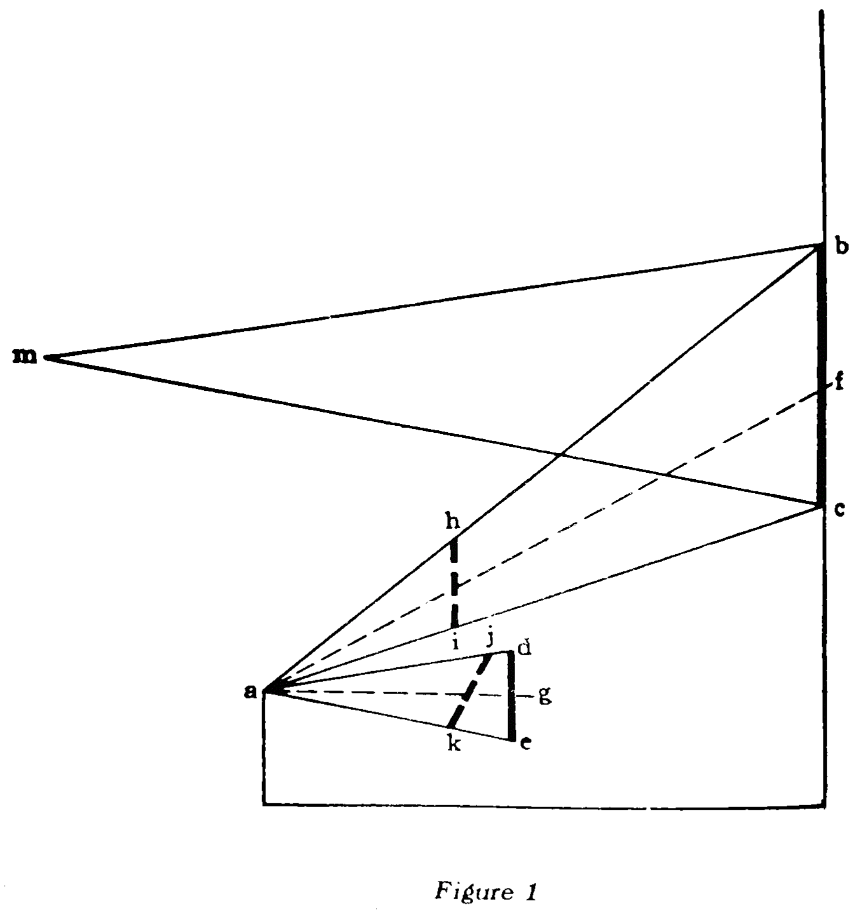

Figure 62 Diagram showing various possible viewpoints of the eye for various situations (Goodman, 1968, p. 18).

In Figure 62 (p. 189) **b-c** is the façade of a building, **d-e** is a painting of **b-c**, a is an observer of the building and of the paintings, and h-i and j-k are two other possible positions for the painting. **a-f** and **a-g** are lines of sight. The view of the façade at point **a** would look like diagram 'a' in Figure 62 (p. 189). Goodman argues that a picture painted in linear perspective would look like diagram 'b' of Figure 63 (p. 190). Thus, Goodman argues, in order for the painting to satisfy the condition that it should pass the exact same array of light rays as does the view itself, such a painting as **d-e** would have to be held in a strange position, such as **h-I** or **j-k**. As a result pictures made with linear perspective cannot send the same array of light through the eye as would the subject itself, as in order for this to be true paintings would, as a rule, need to be hung in all manner of peculiar angles (Goodman, 1968, pp. 17–19).

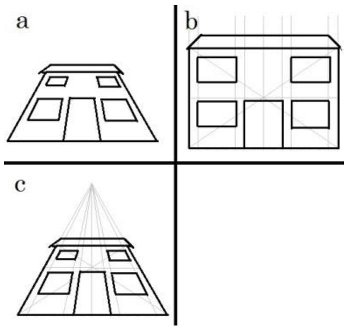

Figure 63 (a) View of b-c from a. (b) Picture, that if held at h-i or j-k, would look like (a). (c) Picture, that if held at d-e, looks like (a). Diagram by the author.

Goodman furthers his argument by reproducing a picture by Paul Klee, Figure 64 (p. 190). He argues

> As Klee remarks, the drawing looks quite normal if taken as representing a floor but awry as representing a façade, even though in the two cases the object represented recede equally from the eye.

(Goodman, 1968, pp. 16, footnote 16)

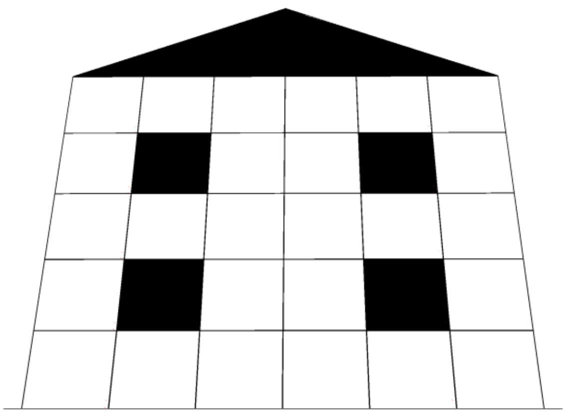

Figure 64 Diagram by Paul Klee, reproduced in Goodman, adapted by the author.

We will look further at this argument of Goodman later, but what is of importance for now is to note that Lopes wants to take the idea of pictorial systems from conventionalism, but wishes to distance himself from the notion of the arbitrariness of depiction. One way that Lopes has done this is by considering the notion of realism in art. He uses the argument of *revelatory realism* to explain this:

> contemporary viewers of Giotto's frescoes expressed astonishment at his accomplishments, praising his pictures as perfect representations of the world. Since Giotto's technique was by no means familiar to them, its realism was of the revelatory variety.

(Lopes, 1995, p. 280)

Giotto's paintings seemed stunningly realistic to his contemporaries. But if we accept Goodman's idea that pictures are composed of arbitrary symbols like a language, Giotto's paintings should not only be unrealistic, but hardly understandable: hence leading Lopes to deny conventionalism.

We might note, though, that the notion of a symbolic language in art does have a history, and thus we might note that symbolic language does have a role to play in depiction, while noting that it plays only a certain role. For example, the nineteenth century Symbolist critic Georges Aurier wrote that objects should be seen

> … only as *signs*. They are the letters of an enormous alphabet of a mystical language, but now he emphasizes the esoteric, mysterious quality of this alphabet.

(Aurier, 1891), quoted in (Karmel, 2003, p. 6)

Something of this can be seen of this with the painting *Cross in the Mountains* (1807–08) by Caspar David Friedrich (1774–1840). While being careful not to overstate the case, we might note that there is little actually depicted of the cross: we recognise the shape, but overall its depiction is sketchy. Its reference is based on the huge amount of cultural memory seeing a simple cross shape would bring to the minds of those who lived in a Christian culture (Lucie-Smith, 1972, p. 28).

Though he dismisses the idea that pictures are composed of arbitrary symbols, Lopes extracts from conventionalism the idea that pictures belong to systems. It is the way these systems are based on recognition processes that forms the heart of his theory.

Lopes delineates his theory thus:

> I suggest that a picture is a representation whose content presents a 'spatially unified' aspect of its subject. By this I mean that every part of the scene that a picture shows must be represented as standing in certain spatial relations to every other part. What these relations are is not absolute or fixed for every picture alike. Pictures present a variety of different kinds of spatially unified aspects, depending on what relations are selected and what are precluded. There is no reason why the spatially unified aspects that pictures embody must be those definitive of Albertian pictures, for instance.

(Lopes, 2004, p. 126)

Lopes notes that in such a definition of a picture the spatial relations form different systems: Albertian, curvilinear, First Nation split-style, axonometric. He notes that each style has particular 'commitments' and more importantly *explicitly* lacks other 'commitments', which he argues is a defining feature of pictures. A linguistic statement such as 'the bear has four limbs' commits to the number of limbs the bear has, but says nothing about the overall distribution of its appendages; it is thus *implicitly non-*

committal about the position of the bear's limbs. A First Nation split-style picture might delineate the same notion of a bear having four limbs but it cannot get away from positioning the limbs on other parts of the depicted bear relative to each other in the picture.

This might lead us to the conclusion that the picture will have to follow the positioning of limbs in the real bear, thus leading us to say that a picture has to be *committal*. However, in fact a picture might distort the bear's limb distribution, for example to fit onto a canoe paddle as in First Nation pictures. Hence, Lopes argues for a more general theory of depiction. The picture of the bear distorts the positioning of the limbs, thus making it clear it will not comment on the bear's limb distribution: Lopes might thus say the picture is *explicitly non-committal* about this feature of the bear (Lopes, 2004, p. 129).

We might note that Lopes is left with a problem. How can we recognise such a paddle-shaped bear as a bear? In English, we simply see a bear and learn that such a creature is known by one of the following sounds: /beː/, /beə/, or /beə(r)/, and one of the following collections of symbols: 'bear', 'Bear', or 'BEAR'. But how would we know that a First Nation picture is of a bear?

One way of answering this is to say that in certain features resemble those of the object depicted, though as we saw earlier Lopes rejects resemblance theories. How, then, does Lopes explain recognition? In order to answer this question, we should firstly examine how Lopes's theory relates to vertex depiction.

Lopes argues that recognitional systems can be said to be *dynamic*. This explains an important point, namely that if we see an object from one angle, we can recognise it from another angle. Lopes argues that pictorial systems are similar, which causes pictures to have three properties: pictures are dynamic (i.e. the same object can be recognised in different conditions), pictures have generativity (i.e. if one object can be recognised under diverse conditions then so can others), and pictures have elasticity and thus diversity (i.e. explaining why there can be different pictorial styles). As Lopes says:

> My suggestion is, in sum, that pictures embody information enabling viewers to recognize their contents and their subjects. The recognition skills we bring to pictures depend on and extend the dynamic recognition skills exercised in ordinary perception. I have argued that recognition is not reducible to description, that it is dynamic, aspectual, and systematic, and that this explains the diversity and generativity of depiction. The task for philosophy ends at identifying these structural and logical properties of recognition and their implications for thought and reference.

(Lopes, 2004, p. 149)

We might observe that this is a very good way of describing vertices. To understand this note how the three types of vertices might appear in a picture, such as the photograph in Figure 65 (p. 195).

Figure 65 Lobby in Gropius's MetLife Building, formerly known as the Pan Am Building. Photograph and additions by the author.

The crucial point here is that the same vertices will appear different from different viewpoints. Imagine for a moment a Y-vertex on a cuboid, such as in the leftmost diagram of Figure 67 (p. 198). If we move our eyes downward, we note that the vertex becomes a T-vertex, as in the middle diagram. If we continue to move our eye downwards, we note that the same vertex becomes an arrow-vertex, as in the right-most diagram.

Lopes's idea of aspects thus explains three features of vertex depiction. Firstly, recognition of geometric volumetric forms in pictures can be said to be dynamic, i.e. an object in a picture can be recognised from a variety of angles. This corresponds to the point in Biederman's theory that object recognition is often viewpoint-invariant. Secondly, many objects have vertices, and thus the properties of vertices are generative, or to put it another way it is not limited to one object. This corresponds to Biederman's idea that viewpoint-invariant recognition explains the visual system's ability to recognise large amounts of objects quickly, rather than having to search through memories of huge amounts of previously seen objects. Thirdly, the fact that the visual system looks for vertices of objects allows for a certain degree of elasticity in depiction. A volumetric form, such as one of Giotto's buildings, might not be accurate according to linear perspective, but if the vertices are in the right relative positions, the viewer will identify a volumetric form. In terms of picture production, Giotto therefore had a degree of elasticity in producing volumetric forms.

Figure 66 Photographs of cuboid showing a vertex at different angles. Photograph by the author.

RESEMBLANCE AND INFORMATIVENESS

We can now bring resemblance and informativeness together, explaining both how we will do this, and also why.

Lopes is against the notion of resemblance. We might look at again the quote we saw in the last section:

> Let me reiterate that this is not to deny that pictures are experienced as in some sense like their subjects. My position is nicely expressed in Max Black's assessment of the resemblance theory as, 'uninformative, offering a trivial verbal substitution in place of insight. … The objection to saying that some paintings resemble their subjects is not that they don't, but rather that so little has been said when only this has been said.'

(Black, 1972, p. 36), quoted in (Lopes, 2004, p. 35)

We might begin by looking closely at Lopes's concept of the 'independence challenge'. Lopes's explains this by analogy with signs from American Sign Language:

> Some, like the … sign for 'truth', obviously do not visually resemble what they stand for … Understanding these signs neither depends upon nor promotes any perceived similarity between them and their referents. Other signs we can grasp just by noticing their resemblance to what they signal; the ASL sign for a duck can be understood just by noticing its resemblance to a duck. When a similarity can be seen between a sign and its referent without first knowing its meaning, the similarity is 'representation-independent'. The third class of signs consists of those whose similarity to their subjects is evident only once we know what they refer to. Only once you know what the sign for a rabbit stands for do you see its resemblance to a rabbit. Its resemblance to its referent is 'representation-dependent'.

(Lopes, 2004, p. 16)

Lopes uses this analogy to argue that resemblance theories must meet the 'independence challenge', or in other words must look like the objects depicted without the viewer having to know beforehand what the object is supposed to represent. He argues that 'if we do not understand pictures by noticing resemblances, then we notice resemblances as a result of understanding pictures' (Lopes, 2004, p. 36)

If we look closely at what Lopes says, we might note that he does not *per se* deny that features of pictures share properties with what they depict, but only that this is not enough to explain how we perceive them.

Lopes still needs to explain how we can recognise an object in a picture if it is not enough that we simply identify features of the picture with features of the object. Are pictures like the rabbit of American Sign Language, namely that the sign has properties that are the same as a rabbit's ears, namely a similar shape and pointing downward? American Sign Language thus requires that we are told that the sign is the same as that for a rabbit—we cannot work it out for ourselves (though perhaps we may guess). How does it work for pictures according to Lopes?

> Pictorial recognition at this level may be called 'content-recognition', since it consists in recognizing a design as the features making up an aspect of its subject.

(Lopes, 2004, p. 145)

In this Lopes says that a picture resembles not the object in its entirety, but features of the picture resemble features of the object from one aspect.

We might here return to the cuboid seen from different angles that we looked at earlier (Figure 67, p. 198). We might remember that the same vertices will appear different from different viewpoints. The Y-vertex on a cuboid appears as a T-vertex and an arrow-vertex as we move our eyes down.

Figure 67 Photographs of cuboid showing a vertex at different angles. Photograph by the author.

I would argue that these vertices are representation-independent. Firstly, perhaps we should change Biederman's terminology from 'three types of vertices', to 'three aspects of a vertex'. This makes the point that there is only one type of vertex made up of right angles in three dimensions, but it can be seen in three ways. If you see a vertex, you can recognise it as one of three aspects of vertices. Though the vertices appear different from different viewpoints, they still resemble the visual properties of the vertex.

To argue this point more thoroughly, we might begin by counter-arguing that a vertex in a picture does not resemble the real vertex in reality very much, except that each vertex is three lines at a point. In the case of a T-vertex, it is perhaps not even three lines, but two, one intersecting half-way along another. If the vertex resembled reality, it could not change its resemblance due to changes in the viewer, such as movements of the eye.

Goodman made a similar argument, as we noted earlier in the figure of the house seen from different angles, reproduced here for convenience as Figure 68 (p. 199).

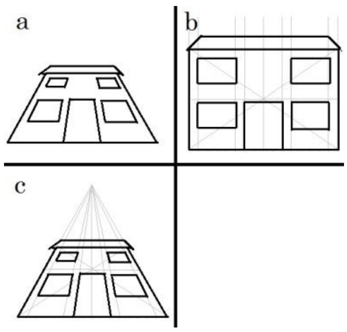

Figure 68 (a) View of b-c from a. (b) Picture, that if held at h-i or j-k, would look like (a). (c) Picture, that if held at d-e, looks like (a). Diagram by the author.

Diagram c is indeed the very picture Goodman says cannot exist, namely a depiction of the façade as it would look from the ground. We should note that not only is such a picture possible, but it does not look very at all odd.

In fact, such viewpoints are very common in art, especially with the three-point perspective used in comic books such as *Spiderman* (Figure 69, p.200). We can thus say that pictures that use linear perspective can indeed send the same array as light as would the subject itself, and we are no further with a solution to our dilemma.

Figure 69 ***Spiderman.*** **www.wildsound-filmmaking-feedback-events.com/spiderman_art.html**

Before dismissing Goodman, however, we should note that there is some truth in what he says about pictorial conventions. While the *Spiderman* viewpoints are common in comics, and not unknown in fine art, it should be admitted that artists have tended to favour a particular viewpoint. This viewpoint is that of the eye directly facing the scene, where the horizon is neither too high nor too low, but in the middle of the scene. It could be argued that although linear perspective does indeed resemble reality, it is often used simply as a convention in which objects can be arranged around a canvas.

Goodman's argument that linear perspective is merely a convention is readily extendable to the notion of vertices. We might well see the three types of vertex, T, Y, and arrow, as merely labels for occlusion, internal vertices, and externals vertices respectively. However, just as linear perspective presents a viewpoint that sends the same array of light through the retina as does the eye itself, so do vertices, allowing us to say that such pictures and their subject matters share vertices.

As noted earlier, though, Lopes has objections to Goodman. Hence to further the point we might note that John Hyman makes an argument about the resemblance of 'occlusion shapes' that we can apply in order to further this argument that depicted vertices resemble reality. Hyman has developed the concept of an 'occlusion shape', namely the outline shape of an object as seen by an observer. The outline shape of a coin, for example, may look either circular, elliptical, or as a straight line, depending on which angle it is viewed at. Hyman writes:

> The answer to the question, "What is really elliptical when a coin looks elliptical despite really being circular?" is that the face of the coin is really circular and its occlusion shape, relative to an oblique line of sight, is really elliptical.

(Hyman, 2006, p. 79)

Hyman uses the notion of an occlusion shape to answer the question of whether the elliptical shape of an object is a 'real' thing, or just part of our mental processes. Hyman writes:

> It can be pointed out that as Columbus sailed away from the harbour in Cadiz he could see the distance to the harbour growing steadily—without the harbour moving by an inch. But this does not show that the changing distance Columbus seemed to perceive was not real or that it

> was merely a feature of his thoughts and sensations. It shows that the distance between two objects depends on both of their positions, which is surely something we already knew.
>
> (Hyman, 2006, pp. 78–79)

In a similar way we can say that the appearance of vertices to a viewer is dependent on the relative positions of the object being viewed and the viewer. Hyman notes the objection that the elliptical shape of a circle cannot be predicated of the circular object. In a similar way, it could be objected that whether a Y, T, or arrow vertex is seen by a viewer cannot be predicated of the vertex itself. However, just as the distance between Columbus and the harbour was not merely a feature of his thoughts and sensations, but a real physical thing, the relative position of the viewer's eye and the vertex is a real physical thing. We can thus say that while vertices do indeed change depending on viewpoint, they nevertheless are something real. Lopes writes:

> But not all pictorial aspects are aspects that could be presented in ordinary visual experience. Resemblance theories wrongly restrict the range of recognizable aspects that pictures may present to those that could be presented in ordinary perception.
>
> (Lopes, 2004, p. 147)

We might reply: yes and no. The sort of strict resemblance view, whereby a picture has to represent as if it were a photographic plate in placed in the eye's pyramid of vision, would indeed wrongly restrict the range of recognisable aspects by excluding Picasso's and First Nation pictures. But the idea that a picture can be composed of *features* that resemble those of an object, while possibly deviating from them in certain respects, makes it possible to say that a picture can in some respects resemble an object, as well as being dynamic, and also possibly deviating from resemblance in other respects.

To harden this, and argue that resemblance is essential to depiction, it might be worth returning again to Lopes's actual statement of depiction:

> I suggest that a picture is a representation whose content presents a 'spatially unified' aspect of its subject. By this I mean that every part of the scene that a picture shows must be represented as standing in certain spatial relations to every other part. What these relations are is not absolute or fixed for every picture alike. Pictures present a variety of different kinds of spatially unified aspects, depending on what relations are selected and what are precluded. There is no reason why the spatially unified aspects that pictures embody must be those definitive of Albertian pictures, for instance.

(Lopes, 2004, p. 126)

The key point here is that 'every part of the scene that a picture shows must be represented as standing in certain spatial relations to every other part'. Imaging a picture of a face, made up of two circles and a line underneath. How are we able to recognise it as a face? Because of the spatial relationships between the elements. In Figure 70 (p. 204) the only recognisable picture is the left-hand one. Lopes does not argue *why* we might be able to recognise such an image as a face. In the argument of revelationary realism, Lopes argues against convention. What allows us to recognise the left-hand picture as a face is thus that it shares visual properties with a face, namely that of spatial relationships, which we might note, following Hyman, are real things.

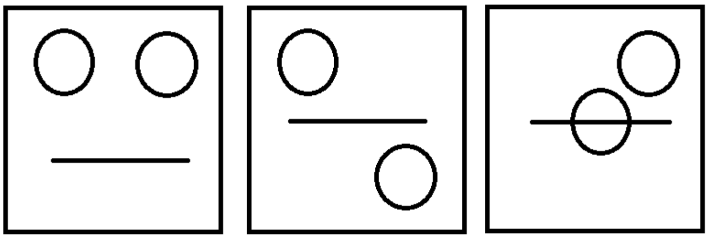

Figure 70 Three pictures of faces. By the author.

We might note two issues arising from this. Firstly, there is the issue of Gombrich's ideas about conventionalism. Gombrich's conventions are very different from the arbitrary conventions of language. He wrote:

> No medium illustrates the code character of this gradiation more clearly than that of the mosaic. Four graded tones of tesserae will suffice for the mosaicist of classical antiquity to suggest the basic relationships of form and space.

(Gombrich, 1960, p. 37)

We might note again that it is relationships that count. To create a three-dimensional form in a flat mosaic that is reasonably lifelike we need, according to Gombrich, four types of tesserae, of four different tones. Imagine we wish to create a picture which has an object with sides of reflected brightness of 10, 35 and 42 lumens under a given light source. (Lumens being a measure of light intensity.) To make a mosaic to hang in a gallery of the same light source that strictly resembles the object the tesserae would have to be of three types that reflect 10, 35, and 42 lumens.

Just say we use tesserae of 5, 20, and 30 lumens reflectance instead. It would not be true to say that our mosaic does not resemble the object. There is a visual property that that is similar to both: namely the relationships between the brightnesses, namely that $10 < 35 < 42$, and $5 < 20 < 30$.

We might now turn to the second point, which Gombrich called 'the beholder's share' (Gombrich, 1960, p. 154). We might argue that pictures resemble the objects they depict, but we must also note that there are limitations to the extent to which they resemble. An arrangement of lines in a picture drawn in linear perspective can be said truly to map the array of light that would enter the pupil from a similar set of lines in reality. However, while the left-hand face of Figure 70 (p. 204) does have visual properties that are shared with a real face, but it does not share very many properties, and perhaps Lopes might remind us a cyclops would not recognise it as a face.

We might, perhaps, note there are different types of pictures. Albertian pictures attempt to reproduce the array of light that enters through the pupil. Such an approach has its successes in its aims, as with linear perspective, and also occasional failures. (We noted earlier that a picture of a yellow daffodil on a television screen might appear very lifelike while in fact being made up of pillarbox red and green light.) Picasso had the opposite approach, and wandered far from attempting to reproduce the array of light that enters the pupil from the subject; though unlike many artists of the twentieth century, he never left figurative art. We might draw the conclusion that art may try to copy reality, but, like Picasso's art, if it deviates it must nevertheless always keep some visual properties in common with its subject matter.

CONCLUSION

What, then, can we say that we have learned in this chapter?

Firstly, we saw that a successful picture has to do more than resemble its subject: *Train on a Moonless Night in a Power Cut* is not successful because it provides almost no information about its subject.

Secondly, we saw that linear perspective, namely the apparent convergence of parallel lines, does not provide a reliable way of ensuring that enough information is provided by a picture when depicting volumetric objects. We saw that the psychological theory of vertices, as developed by Biederman, provides artists with a more reliable way of depicting volumetric form successfully.

Thirdly, we saw that Wölfflin's theory of the Classical and the Baroque can be informed by Biederman's theory.

Fourthly, we saw how Lopes's theory of aspects can further our understanding of depiction. Our recognition of objects is dynamic, and this can occur in pictures as well. A picture can present an object from a variety of viewpoints. Furthermore, by noting that objects can be recognised by features, we can see how pictures can deviate from lifelikeness, as we saw with the Giotto and its poor linear perspective. This further explains the varieties of depiction, such as First Nation split-style figures. I also argue that Lopes's theory is not incompatible with the idea that in a picture many of the features will resemble features of the objects depicted.

This leads us to a new understanding of pictures, namely that a picture may leave out certain features, and modify or distort others. The features chosen by the artist provides the information about the subject matter that the artist feels is relevant. The modifications and distortions either aid the presentation, or distort the subject matter.

What information an artist might include or leave out, and how and why the artist might distort or modify the subject, and how this relates to perception and society, is the topic of the next chapter.

CHAPTER 3. FEATURES: WHAT AN ARTIST LEAVES IN, TAKES OUT, AND DISTORTS IN A PICTURE

SCALES • RECEPTIVE FIELDS • CROSS-CULTURAL PSYCHOLOGY AND THE PERIOD EYE

INTRODUCTION

We noted at the end of the last chapter that a picture may leave out certain features of a subject matter, and modify or distort others. The features chosen by the artist provides the information about the subject matter that the artist feels is relevant. The modifications and distortions either aid the presentation, or distort the subject matter.

We now need to investigate which features an artist chooses to leave in, leave out, or distort, what psychological processes are involved in this, and how these processes can explain how omissions and distortions of features affect and facilitate depiction.

This raises an issue that we have not examined up to now, namely that not many pictures actually resemble their subject matter very closely. Ancient Egyptian paintings, the saints in the Book of Kells, and the paintings of Picasso are a long way from sending the same array of light through the pupil as would the subject matters themselves. Yet we are able to recognise Egyptian farm workers, the evangelists, and the residents of Paris. Though Lopes's theory as developed in the last chapter provides a framework for understanding this, we will need to examine the process in a more precise way to provide a fuller understanding.

The chapter examines how the visual system's ability to decompose the elements of a stimulus allows the varieties of depiction to occur. It also shows how the visual system's attempts always to interpret a stimulus allow artists to (a) leave features out, and (b) distort features. Furthermore, it shows that this is because the visual system's attempts to find a coherent interpretation of a stimulus cause it to compensate for (a) the missing features, and (b) the distorted features.

The chapter is divided into three sections. 'Decomposition and Recomposition: Scales (Application of Psychology to Art 5)' (p. 210) examines the ways each different level of visual resolution forms a different aspect in the visual system. This provides an example of the way the visual system divides the stimulus from its environment into different features, and then re-combines them.

'Decomposition and Recomposition: Receptive Fields (Application of Psychology to Art 6)' (p. 245) considers another example of how the visual system divides information into component features, in this case colour and 'black and white', due to different receptive fields. This provides an example of how the visual system allows us to perceive stimuli without all the features being apparent, and thus why artists are able to draw without colour. In addition, we combine this theory with the theory developed earlier in this thesis concerning edge detection in the V1 area, and the theories of converging line and vertex recognition, to form a more complete description of the visual system's line detection faculty, interpretation system, and the depictive possibilities that arise from these.

Finally, 'The Selection of Features in the Creation of Pictures: Perspective, Cross-Cultural Psychology, and the Period Eye (Application of Psychology to Art 7)' (p. 250) examines how the selection and distortion of component features are used to create pictures, building on the ideas of the previous subsection about receptive fields. It also examines Baxandall's theory of the 'period eye', and how he attempts to reconstruct the 'cognitive apparatus' of people from different periods, and thus examine how different ages saw the world in a strictly visual sense.

DECOMPOSITION AND RECOMPOSITION: SCALES (APPLICATION OF PSYCHOLOGY TO ART 5)

INTRODUCTION

One of the most important areas of research in contemporary visual psychology is the theory of *scales*. This section investigates this theory, and what it can explain about art. We will see that scale theory explains how we perceive tartans, and why the Pointillists often painted with different sizes of brush stroke.

The section is divided into six subsections. 'Scales' (p. 211) presents an overview of the psychological theory. 'Tartan' (p. 221) and 'Duccio' (p. 223) examine applications of the theory of scales to visual culture. 'Pointillism' (p. 225) begins the examination of scales in relation to an important area of Post-Impressionism. 'Seurat' (p. 237) extends the discussion of Pointillism in terms of one of its most important practitioners. Finally, 'Conclusion: Scales and the Theory of Art' (p. 243) examines how the theory of scales can illuminate the subject of art history in general, and specifically the topics of the decomposition and recomposition of visual stimuli and the effect this has on depiction.

SCALES

Experiments into visual perception have shown that the visual system breaks down and processes images at different levels or resolutions, with each level containing a varying amount of detail. These levels, known as *scales*, are illustrated by Figure 71 (p. 211). Only two scales are represented in the illustration, a low (blurry) and a high (detailed), but there are in fact many such levels. The diagram shows that the low scale provides more general information about the image, while the high scale provides the details (Blake & Sekuler, 2006, p. 157).

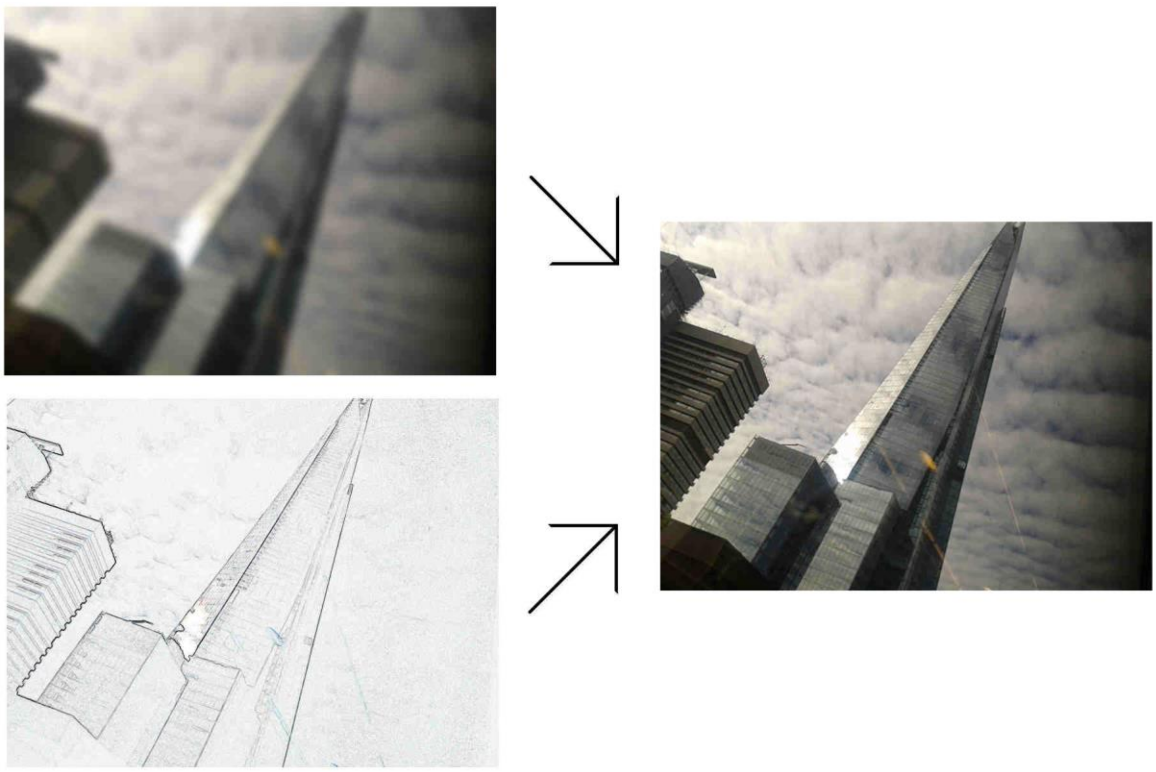

Figure 71 Diagram showing different visual scales and their combination. Photograph, computer processing, and diagram by the author.

Because the visual system integrates the different scales in our perception, we cannot normally perceive the scales separately. Neuroscientists Oliva and Schyns developed a technique of hybrid images to demonstrate the separate scales (Figure 72, p. 212). Two completely different images are present in the illustration. Which of these two images you see depends on the detail that your eyes are able to discern. When far away from the image, the details are less noticeable; when close to the image, the less detailed information is more visible.

The image of Einstein has more detail, and hence when you look closely you see Einstein; the image of Monroe has less detail, and hence when you stand back from the image, you see Monroe. The same effect can be found by squinting, or removing one's spectacles; both will result in greater details being filtered out, leaving the image of Monroe. Opening one's eyes fully and replacing any spectacles will allow the greater detail to reappear, and with them Einstein (Oliva & Schyns, 1997).

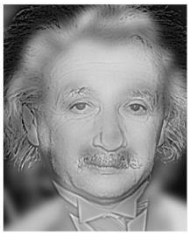

Figure 72 Hybrid image of Albert Einstein and Marilyn Monroe. If you squint or remove your glasses, Albert Einstein disappears and Marilyn Monroe appears. By Dr Rob Jenkins, University of Glasgow.

The Einstein-Monroe illusion is an extreme case where it is impossible to see both images at the same time. Normally, however, the difference in resolution between different scales is not so great. We can thus see a number of scales at the same time without having to squint or walk back and forth (Figure 73, p. 213). It is interesting to note that different species of animal see different scales. Figure 74 (p. 213) shows that cats are sensitive to more detailed stimuli, while humans are sensitive to less detailed stimuli (Bisti & Maffei, 1974).

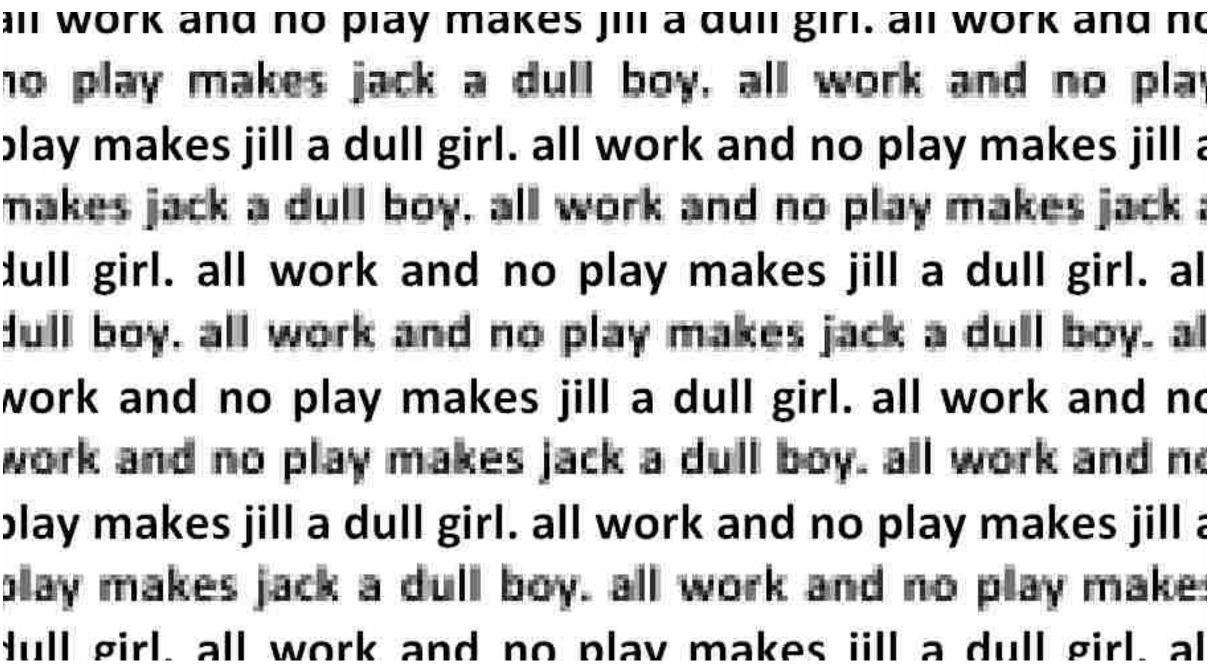

Figure 73 Diagram showing different scales, with the objects in both scales recognisable. Diagram by the author.

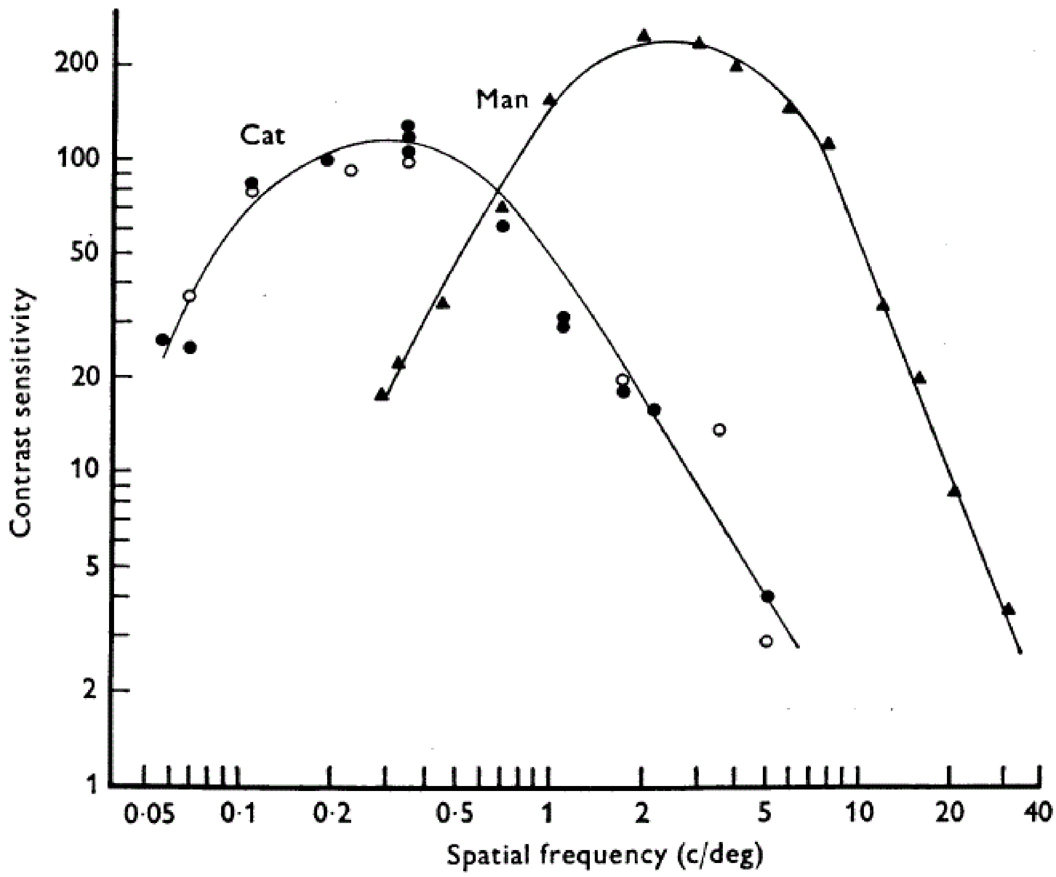

Figure 74 Diagram showing the differences in scale sensitivity between cats and humans (Bisti & Maffei, 1974).

In real life an image's scales tend not to conflict with each other, but artificial images can be created that do conflict, for example the Einstein-Monroe illusion above. Figure 75 (p. 214) also has a mismatch between the less detailed and more detailed information. In this image the less detailed information contains general information about the subject, namely that the picture is a peahen in a cage. The more detailed information, however, such as the details of the peahen's feathers and beak and the wires of the cage, has been replaced by a pixilation scheme.

We might note if both a cat and a human were to see both the real-life peahen and the pixelated photograph, the human, less sensitive to detail, would see the peahen in both cases, but the cat, only able to see the detail, would see the feathers, beak and cage wires in the real-life peahen, but only a meaningless array of squares in the photograph.

Figure 75 Heavily pixelated photograph of a peahen in a cage. Photograph and computer processing by the author.

Neuroscientists have also researched the process whereby the visual system decomposes images into scales. Such research has demonstrated that the human visual system utilises what have become known as *gratings*. Gratings act like filters for visual information, in a process illustrated in a simplified form by Figure 76 (p. 216). The human visual system is illustrated by the middle row of the diagram. Using the sort of filters shown in the diagram, the visual system processes the top image to create the decomposed image elements shown in the bottom row. Figure 77 (p. 217) shows how resolution is important in scale sensitivity, but neuroscientists have discovered that resolution is not the only important aspect of scales. Other properties of importance include contrast, orientation, and phase, as illustrated by Figure 78 (p. 217) (Issa, Trepel, & Stryker, 2000) (Blake & Sekuler, 2006, p. 159).

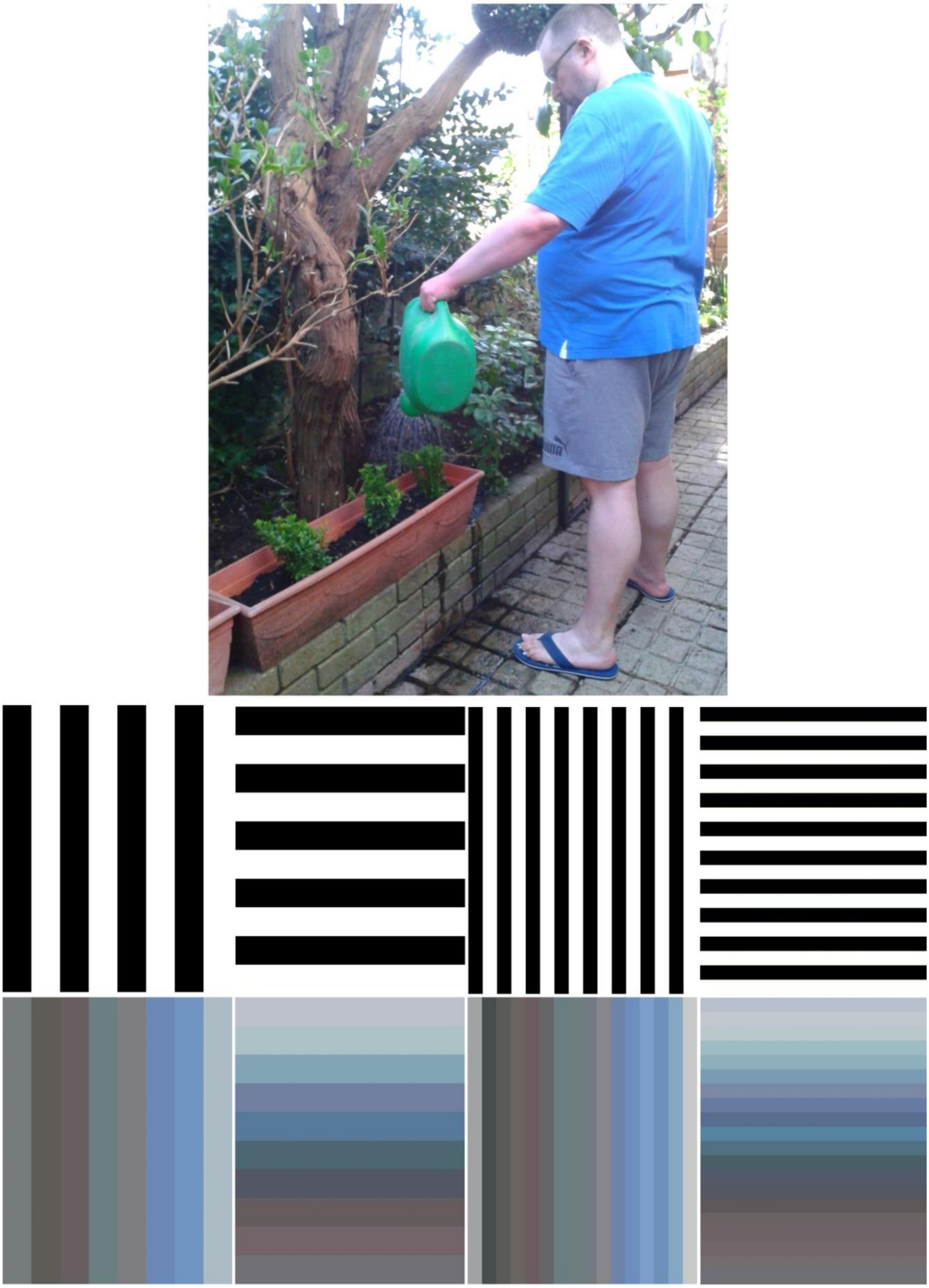

Figure 76 Diagram showing how the visual system decomposes an image into scales. Top: image to be decomposed • Middle: the 'filters' the visual system uses • Bottom: top picture after passing through the filters. Photograph and processing by the author.

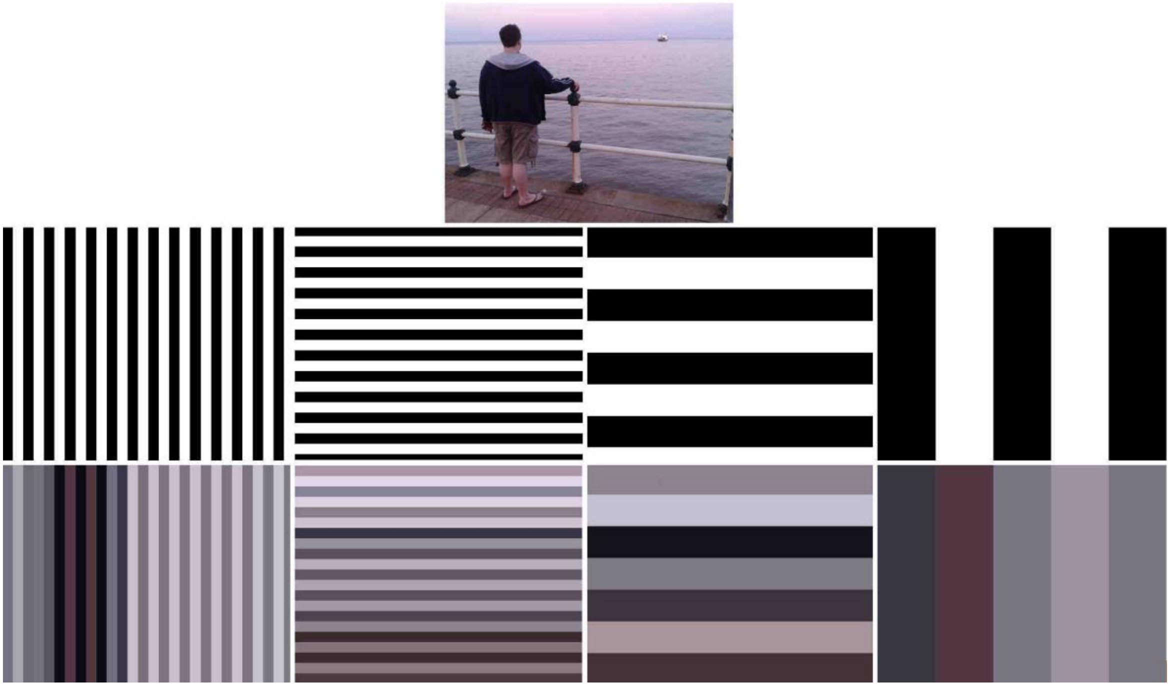

Figure 77 Decomposed elements of a photograph to illustrate resolutions in scales. From left: High vertical resolution • High horizontal resolution • Low horizontal resolution • Low vertical resolution. Photograph and processing by the author.

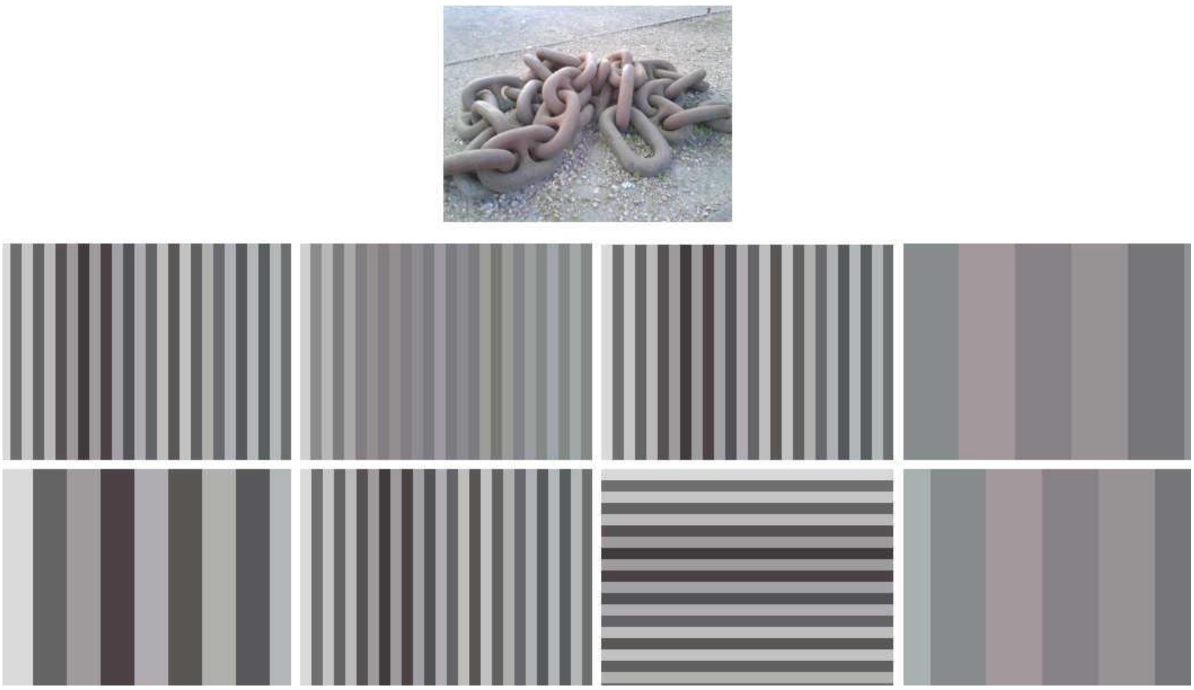

Figure 78 Decomposed elements of a photograph to illustrate different scales. From left: Resolution (lower diagram has lower resolution) • Contrast (lower diagram has stronger contrasts) • Orientation (grids are in opposite directions) • Phase (in the lower diagram the sampling starts slightly to the left). Photograph and processing by the author.

Such decompositions are similar to what is known as the *Fourier transform*. The Fourier transform is a mathematical transformation whereby complex formations of waves, such as those found in images or sounds, are decomposed into simpler components. *Fourier analysis* is the name given to the process whereby an image or a sound is decomposed into its components, and *Fourier synthesis* is the name given to the process whereby the decomposed components are recombined into the original image or sound.

In addition to allowing complex wave formations to be decomposed for analysis, an image or sound transformed by the Fourier transform can be modified in the decomposed state before recomposition. We will see an application of this modification later.

The Fourier transform is best known for its applications to sound and music. The sounds created by musicians are often very complex. For example, one sound in Jimi Hendrix's 1968 song *Crosstown Traffic* is known as the chord 'F#7'. If we look at the top of Figure 79 (p. 219), we see the waveform for the chord F#7 is complex. However, the mathematical technique of the Fourier transform can be used to decompose the chord into simpler waveforms.

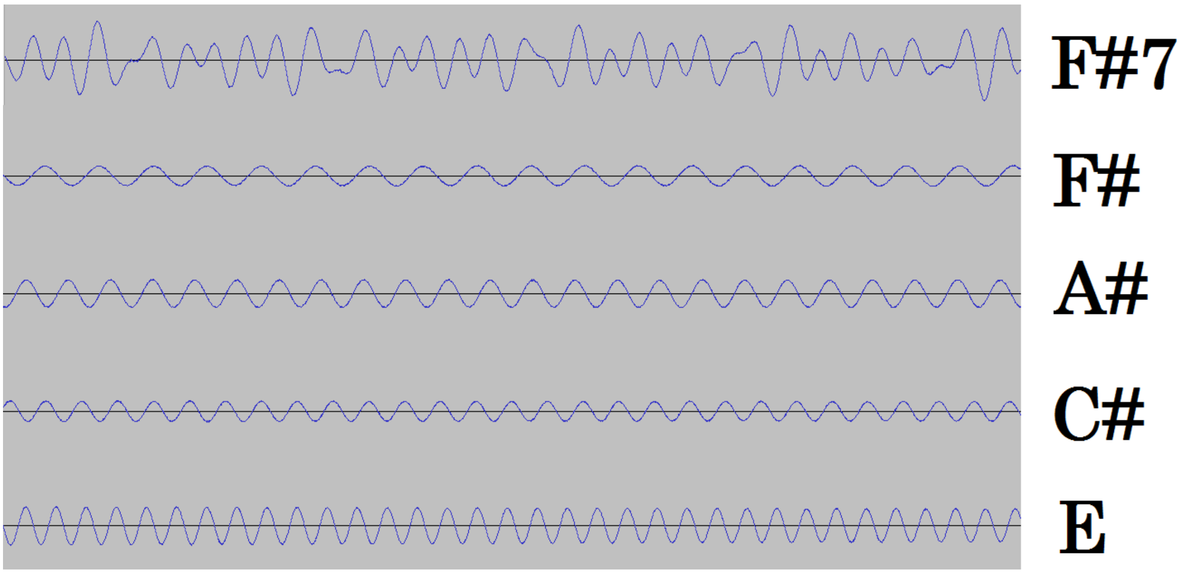

Figure 79 Waveforms of the chord F#7, and the notes F#, A#, C# and E. Diagram by the author.

The Fourier transform tells us that the sound played by Hendrix was made up of other sounds. We might observe that these sounds are the musical notes F#, A#, C# and E.

The mathematical expression of the Fourier transform is

$$y = a + \mathrm{b}\cos x + c\sin x + d\cos 2x + e\sin 2x + f\cos 3x + g\sin 3x + \cdots$$

were 'y' is the mathematical form of, say, the chord F#7, and bcosx, csinx, etc. are the mathematical forms of, say, the notes F#, A#, C# and E.

It is easy enough for listeners to identify chords, and as a result chords are used extensively in Western music as well as other musical traditions such as that of African Pygmy tribes (Turnbull, The Forest People, 1961). The complex chords used by Jimi Hendrix could be readily identified even by casual radio listeners. Psychologists of sound have thus hypothesised that the mental apparatus must perform a similar action to the Fourier transform when listening to chords. Hence, when Jimi Hendrix plucked four strings on his guitar, one tuned to F#, another to A#, another to C#, and another to E, the mental apparatus of members of the audience would decompose the resulting sound from the amplifier, the chord F#7, back into the notes F#, A#, C# and E.

Perceptual psychologists have proposed that the mental decompositions illustrated by Figure 77 (p. 217) and Figure 78 (p. 217) are also essentially the same process as the Fourier transform (Royer, Rzeszotarski, & Gilmore, 1983). Thus, just as the brain performs a process similar to the Fourier transform to decompose chords into simpler sounds, the brain uses a process similar to the Fourier transform to decompose complex images into simple patterns.

This idea has found an application in computing to solve the problem of compressing computer images in order to reduce file sizes. The visual system is more sensitive to certain scales than others. As a result, if these scales that the brain is less sensitive to are stripped out of an image, then the information content, and thus the file size, can be reduced without a noticeable difference in the quality of the recomposed image. The Fourier transform used in computer image compression is thus similar to visual system's process of perceiving only certain scales. Such a compression procedure is used in the JPEG image format, which is used for most internet images and is thus the main way artworks are viewed today. When creating a JPEG file, the image is first divided into 8 x 8 pixel blocks, which then undergo a Fourier transform of the form shown in Figure 80 (p. 221). Note how each cell of the table combines the corresponding cells from the uppermost row and leftmost column. The information stripped out by the compression process is the fine frequency information in the cells towards the bottom-right of the table. The fine frequency information is taken out because, if we recall from Figure 74 (p. 213), humans are less sensitive to this information. We might thus note that most artworks viewed on the internet have large amounts of high contrast and detailed information removed (Pennebaker & Mitchell, 1993).

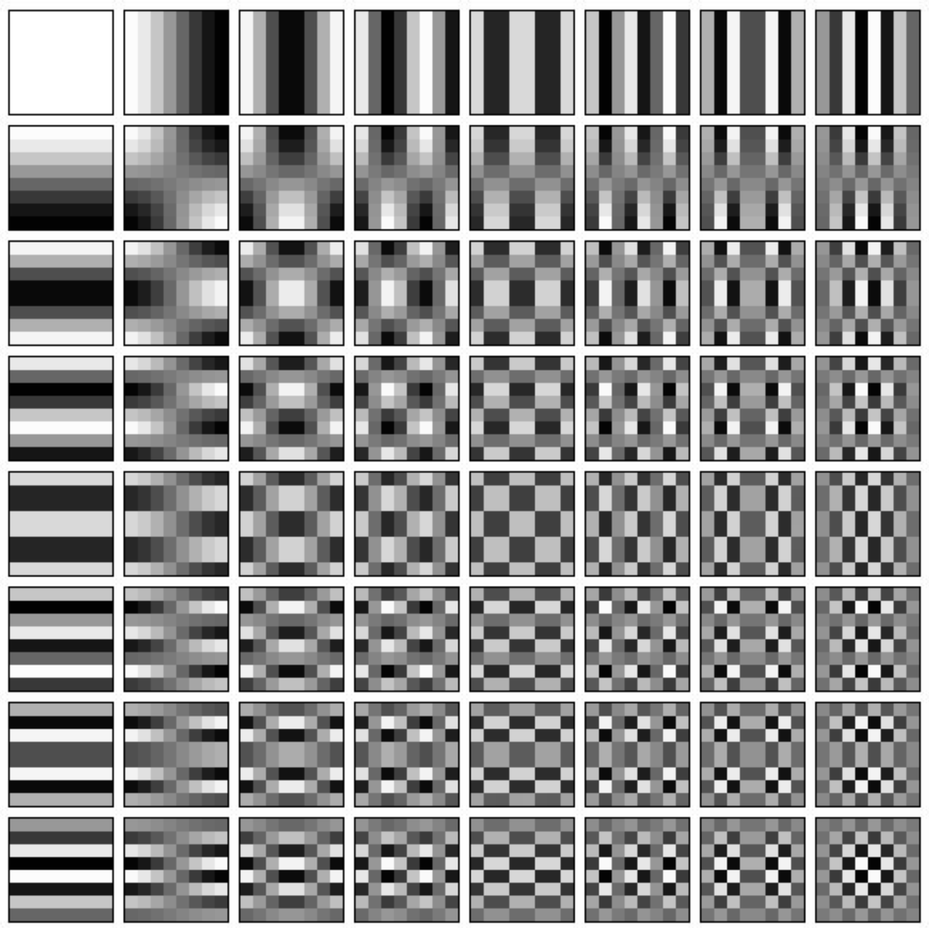

Figure 80 Diagram of the gratings used in JPEG compression, from the mathematical process known as the Discrete Cosine Transformation (Pennebaker & Mitchell, 1993).

TARTAN

Writers have used scales to explain a number of features of art (Livingstone M. , 2002, pp. 71–72). Blake & Sekuler, for example, describe how the textile pattern known as a plaid is processed by the visual system. Figure 81 (p. 222) shows such a plaid, with Figure 82 (p. 222) showing its high-scale element, and Figure 83 (p. 222) showing its low-scale element (Blake & Sekuler, 2006, pp. 159–161).

The decomposition process of scales explains how we perceive a plaid, namely as overlying grids, by decomposing it into a number of scales. We should note that if we did not mentally decompose a plaid in this way, the only way of decomposing it would be into squares and rectangles, as in Figure 84 (p. 223). Complex tartans would thus appear as a jumble of shapes rather than intersecting lines.

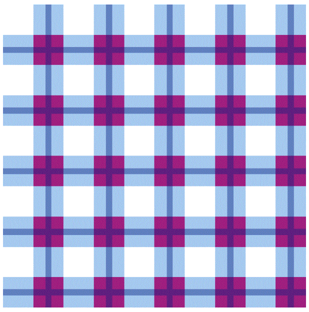

Figure 81 Plaid. Diagram by the author.

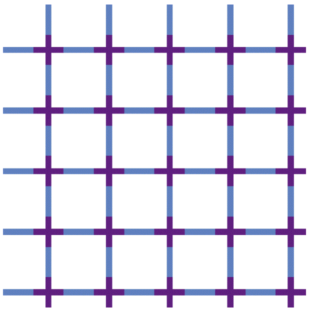

Figure 82 The above plaid's high-scale element. Diagram by the author.

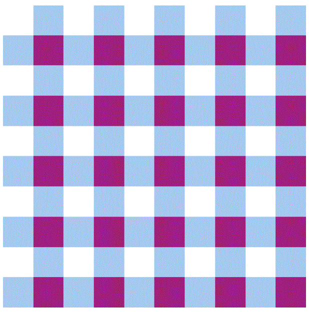

Figure 83 The above plaid's low-scale element. Diagram by the author.

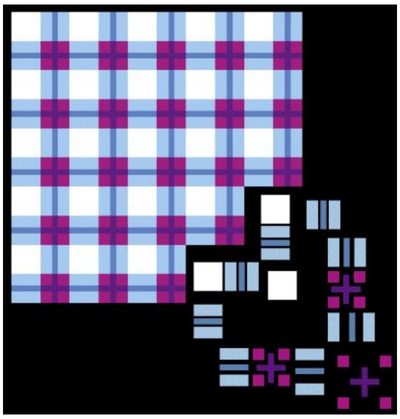

Figure 84 **The above plaid shown as the visual system might decompose it if the visual system did not use scales. Diagram by the author.**

DUCCIO

Scales can also be applied to understanding an inconsistency in the depiction of the background cloth of Figure 85, Duccio's *Rucellai Madonna* (p.224). If you look carefully at the geometric pattern, it does not crease and fold in accordance with the modelling. Instead, Duccio has simply painted the pattern as if the cloth is flat, and then glazed the modelling directly over the pattern.

Why is it, then, that we can perceive the painted cloth as a cloth, when such a fabric could not exist in reality? The theory of scales can be used to explain this. The cloth can be divided into two scales, that of the underlying geometric pattern, a high frequency/high contrast scale, and that of the cloth's modelling, a low frequency/medium contrast scale (Figure 86, p. 224). That the background appears as a draped cloth, despite the inconsistency in the depiction noted above, implies that the visual system processes the two scales of the cloth separately. The trick Duccio used in his painting of the cloth is not noticed by the viewer on first inspection, due to the visual system's decomposition of the image into separate scales.

Figure 85 **Duccio di Buoninsegna. *Rucellai Madonna.* 1285. Florence: Uffizi Gallery. (Detail.)**

Figure 86 **Duccio di Buoninsegna. *Rucellai Madonna.* 1285. Florence: Uffizi Gallery. (Processed detail.) Outer square: background cloth with finer scale; inner square: background cloth with lower resolution scale. Processing by the author.**

POINTILLISM

This subsection uses the theory of scales to explain how we perceive Pointillist paintings. We shall begin by considering the point that in some ways, Pointillist paintings are rather odd. Consider, for example, *Grand Canal (Venice)* (1905, Toledo, Ohio, Toledo Museum of Art) by Paul Signac (1863–1935). The surface of the canvas is covered with fairly large slabs of paint. Somehow, though, we are able to see boats, jetties, domes, columns and reflections in the painting. How are we able to see objects in such a painting where the painting is very obviously composed of brush strokes?

This phenomenon, of collections of visible brush strokes making up objects in paintings, of course goes on outside of Pointillism. An example of this can be seen in Vincent van Gogh 1888 *Sunflowers* (London, National Gallery). A smooth impasto describes the shapes and textures of the petals, while a thick stippling impasto describes the brown centre of the flowers. Similar examples can be seen in van Gogh's 1888 *Bedroom in Arles (first version)* (Amsterdam: Van Gogh Museum), where we see that the wood on the floor and the bed is painted with long brush-strokes that describe the longitudinal aspect of the wood grain, and thick, linear impasto lines describe the wickerwork of the seats. However, the more regular size and arrangement of the brush strokes in Pointillism will provide us with a more readily analysable example.

Pointillism was an artistic technique initially developed by the French painter Georges-Pierre Seurat (1859–1891). The development of Pointillism was complex. Furthermore, writings about its history have been characterised by confusion. Before we use scales to explain the perception of Pointillist paintings, we will need to examine the history of Pointillism and disentangle its multifaceted theoretical background. We shall see that the confusion surrounding it was a product not only of the writings about Pointillist artists, but the understanding of science by the Pointillists themselves, and most notably Seurat.

Misapprehensions about Seurat's work date to his first critics. For example, in 1886 naturalist writer Paul Alexis described Seurat as a 'violently sincere Impressionist', seemingly ignoring the contrast between Seurat's slow, considered, working methods and the fast, *en plein air* approach of early Monet and Renoir. Smith finds another example of misapprehensions about Seurat in Alexis's attempt to link Impressionism with a Positivist, anti-Idealist ideology, which Smith notes was in opposition to Seurat's view of the consistency between a belief in the material world and idealism. Smith also notes that Seurat may not have discouraged writers like Alexis from making their comments. Critics expressing a variety of interpretations would have given Seurat a commercial advantage, by letting a potential buyers see in his work what they wished (Smith, 1997, p. 4). Seurat, then, might be considered as possibly encouraging the confusion that has surrounded his work.

Another view of Seurat is that he took from Impressionism only its approach to colour, and that his work is a methodical application of scientific principles. This tends to be the view of Seurat that has filtered down into popular understanding. Consider, for example, this extract from the article on Pointillism from the popular *Purnell's New English Encyclopedia* of 1965:

> By temperament Georges Seurat was a highly disciplined artist who was born with a scientific interest in his forms and the relationships of colour and volume. He took up the ideas of Chevreul and applied them

> systematically, evolving a technique that built up colours and shapes with a multitude of small dots.
>
> (Wolfenden, 1965, p. 4804)

We will see that the idea that Seurat methodically applied science is somewhat distant from the truth. Alan Lee argues that the lack of critique of Pointillism's somewhat suspect science has perpetuated a distorted view of Seurat's work into more recent times (Lee, 1987, p. 205).

To begin with, then, it will be of use to outline briefly the historical and theoretical development of Pointillism. We should start with the observation that Seurat did not begin as a Pointillist. His first major painting, the 1884 *Bathers at Asnières,* is a transitional work. Mostly this painting is not in the Pointillist method, in fact veering away from the broken colour of the Impressionists. This is especially notable in the even gradiations of tone of the skin of the shirtless bathers, reminiscent of Ingres' 1808 painting *The Valpinçon Bather*. Indeed, Ingres was the teacher of Henri Lehmann, Seurat's own teacher (Düchting, 1999, p. 8).

Bathers at Asnières contains some of the main features that we associate with Seurat's work: the lengthy compositional process, and the emphasis on balancing colour and tone to create both a balanced composition and a convincing depiction of three-dimensional space. This indicates that Seurat's artistic concerns lay beyond Pointillism. It was with *Bathers at Asnières,* however, that we see the beginnings of Pointillism.

A few years after it was first exhibited, Seurat began to add Pointillist elements to the painting. This is most notable in the hat on the bather on the far right, which Seurat covered with orange dots. His next major painting, *A Sunday Afternoon on the Island of La Grande Jatte* (1884–1886) was similar in being a frieze-like depiction of Parisians at leisure by a river. *La Grande Jatte,* however, was painted with full-blown Pointillism (Leighton & Thomson, 1997, pp. 81–82).

What, then, was the motivation for Pointillism? The main works normally cited as the source of Pointillist theory are the writings of French chemist Michel Eugène Chevreul (1786–1889). As we saw earlier, Chevreul developed two of the most important ideas used by the Pointillists, namely *optical mixing* and *simultaneous contrast.* Optical mixing involves observing that instead of mixing two colours of paint on a palette, for example mixing cyan and yellow to make green, colours can be mixed optically, as with the dots used in Pointillist paintings. Simultaneous contrast describes the feature of the visual system that two colours placed next to each other appear to accentuate in the mind each other's properties. Hence putting a dark colour next to a light colour will make the dark colour appear darker and the light colour appear lighter, and putting blue next to yellow will make both the blue and the yellow appear more intense (Düchting, 1999, p. 45).

We tend to associate optical mixing with the Pointillists, though it would have been known long before. We shall examine the Pointillists' use of optical mixing in the next subsection, but it is useful to note that it is something that has been widely used in art. This was certainly known to artists of the Italian pre- and early-Renaissance. Painters such as the Master of Saint Francis (active c.1260–c.1272), Duccio di Buoninsegna (active 1278, died 1318/19), and Ugolino di Nerio (active 1317, died 1339(?)), created tone by using fine hatched brushstrokes (Bomford, Dunkerton, Gordon, & Roy, 1989, p. 28).

Mosaics would be an obvious example of a type of artwork that uses optical mixing, and this is certainly true for large mosaics used on high ceilings, intended to be seen by viewers far beneath. However, many mosaics were intended to be seen close up, and thus for optical mixing to have been a goal artists would had to have used very small tesserae, something that was quite rare (Demus, 1953).

The normal account of Pointillism is that Seurat, searching for a scientific basis for colour, adopted the ideas of Chevreul. This, however, somewhat oversimplifies the situation.

In order to explain this we might begin by noting that the use of a range of different hues in broken colour to brighten the image long predates Seurat. Gage quotes Delacroix's discussion of Ingres:

> He has interspersed in his coiffures, in his fabrics, in his fillets, a lilac of exquisite freshness, coloured borders and the attraction of a thousand pretty ornaments, but they do nothing at all to create colour. The livid and leaden tones of an old wall by Rembrandt are far richer than this abundance of clashing tones applied to objects which he will never get to relate to one another by reflections, and which remain crude, isolated, cold and gaudy.

(Sand, 1896, pp. 77–79), quoted in (Gage, 1993, p. 201)

Consider, say, Rembrandt's 1661 *Self Portrait as the Apostle Paul* (Amsterdam, Rijksmuseum). The paper of the book in the painting is painted with an array of red earths, yellow ochres, and a number of shades of greenish-grey. Many of these tones are juxtaposed rather than merged to create the overall colour of the paper. Broken colour would again reappear in Impressionism, making the past masters of painting an alternative to Chevreul as a reason for adopting broken colour.

Alan Lee argues that there were two main aims for Pointillism: a desire for painting to reflect natural processes, and the desire to use natural processes to enhance the strength of the colours in paintings. These combined desires caused Seurat to study (though not very diligently) the work of a number of scientists, including Newton, and notably Chevreul. Artists and writers other than Seurat were studying colour science and optics at the same time. We shall see both the positive influence of, and the problems caused by their often somewhat less-than-scholarly approach to, science (Lee, 1987, p. 204) (Gage, 1993, p. 175).

Additional confusion occurs by the fact that the artists involved in Pointillism and Post-Impressionism did not always produce clear written statements about their theories and practices. The contemporary critics who stepped in to fill this gap were not always especially reliable. Art writer Félix Fénéon (1861–1944), for example, had an ambiguous relationship with Seurat, and Seurat would alternate between approval and disapproval of Fénéon's assessments of his techniques.

Seurat may well have been influenced by science, but perhaps there are other reasons for adopting Pointillism. If we again look at Seurat's 1884 *Bathers at Asnières,* we see that he produced a large number of preparatory sketches and paintings, indicating a desire to work in a methodical fashion to produce a balanced composition. This is somewhat different to the Impressionist desire to capture the fleeting 'Impressions' of light. However, Seurat can be seen to be interested in some areas of Impressionism, namely the compositional benefits of broken colour. If we return again to the quote by Delacroix above, we note that Delacroix observed that Ingres's paintings are composed of 'objects' that are 'isolated'. In contrast, a wall, which would generally be considered homogeneous in colour, is painted by Rembrandt in a range of colours that, in contrast with Ingres, inter-relate.

This notion of using the areas of broken colour to inter-relate every portion of a painting, rather than merely the objects within a painting, can be seen as a reason for Seurat to adopt the Pointillist method. Furthermore, Pointillism allows painters to take the method of all-over composition a stage further; if one can hardly see the points in a Pointillist painting, then the composition would be more or less invisible to the eye, and would thus allow for a totally integrated painting (Lee, 1987).

Might we say, then, that Lee is wrong in arguing that Seurat's paintings can be seen primarily as a product of the application and misapplication of scientific ideas? Was Seurat, perhaps, instead influenced by ideas of art that had been developed within artistic environments and circles, and not by scientists? We will see that this is not the case.

Seurat and other artists of the time had discovered in Newton's writings that light is made up various pure 'spectral' colours, and that all other colours were various admixtures of these colours. It would seem that Chevreul's theory of optical mixing could be combined with Newton's theory to provide a natural basis for painting. Newton had discovered that the rainbow contained all the colours that made up light. Seurat and other artists were captivated by the idea that what hit the eye were these spectral colours, and felt that by using only these colours an artist could copy the processes of light itself. If brought together with the theory of optical mixture, it becomes possible to imagine an artistic technique that follows the very processes of nature. One begins with the spectral colours, and make mixtures of these not on the palette, but on the eye.

This is what occurs in nature, according to the ill-conceived combination of the theories. We will see how these Pointillist theories were based on a poor understanding of science, but that the approach was nevertheless attractive, and perhaps artistically useful. We will also see what specifically the problems with Pointillist theories are (Düchting, 1999).

It is, then, most reasonable to conclude that the reasons behind Pointillism are multi-faceted. Seurat certainly investigated science, but perhaps did not systematically evaluate his reading. He could, perhaps, be said to have picked up ideas and used them if they appeared useful and attractive, rather than carefully understanding and appraising them. The confusion this causes for historians is compounded by the fact that the half-understood science nevertheless often opened up artistic opportunities for Seurat, meaning that the half-understood science metamorphosed into successful art. We are thus left with Pointillism being a soup made of the following ingredients: artistic ideas unrelated to science (such as the use of broken colour to aid overall composition), badly understood science with little artistic value, well understood science with artistic value, and misunderstood science with co-incidentally good artistic results.

It is with Chevreul's two theories that these different uses and abuses of science can be seen. Art historians often argue that the use of these two theories by Pointillists is often confused. Pointillists believed that optical mixes made of small dots of contrasting colour would be more vibrant than colour mixes made on the palette, due to a combination of the effects of optical mixing and simultaneous contrast. Certainly, that the contrast of different hues results in more vibrant hues is beyond doubt; this can be seen beyond Pointillism in the Renoir illustration we saw earlier (Figure 27, p. 118). The actual colour of the boat is the same in both pictures, but the boat appears to be a much richer orange in the left picture than the right due to the simultaneous contrast effect. We can thus say that there is one genuine and correct use of science (Düchting, 1999, p. 45) (Lee, 1987).

Roy notes how Renoir uses optical mixture with some subtlety. The foreground of the picture is quite Pointillist in its approach, with the paint strokes of the grass and the ripples in the foreground being large and clearly discernible to the eye, though without too much variation in size. We might thus be reminded of the large dots of a Signac painting. A chemical analysis of the foreground paint shows that much of the painting follows the same technique as Seurat, namely pure colours with only white as an additive. The middleground sees the areas of paint becoming smaller, but the background dispenses with most optical mixing, and is formed mainly with palette mixtures. We thus see Renoir using the notion that optical mixing creates vibrant areas of colour in order to delineate pictorial space. The vibrant optical mixtures of the foreground proceed from the picture, while the duller palette mixtures recede (Roy, 1985, p. 19).

It is the use of optical mixes that involve simultaneous contrast that is to be questioned. That such optical mixes would not be vibrant can be seen in the top-right image of Figure 87 (p. 234). We note that the yellow and the deep blue, when mixed together optically, create a dull grey. Here we have a totally erroneous reading of science. That such optical mixes could be dull was noted by Signac, who spoke of Pointillist paintings having a ‘veil of grey’. This resulted in Signac developing a technique of larger tesserae-like brush strokes (Düchting, 1999, p. 45).

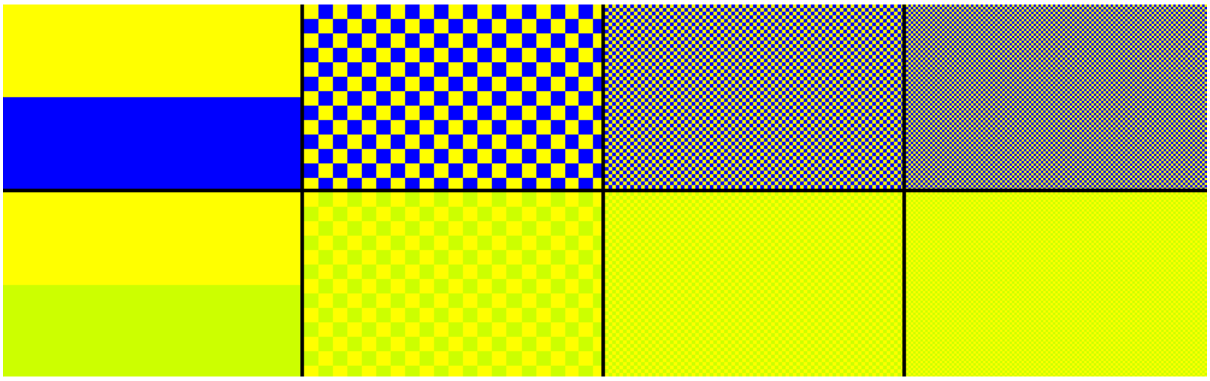

Figure 87 Top row, left to right: Two juxtaposed contrasting colours • Mixture where the separate colours are still visible • Mixture where colours are barely visible • Mixture where colours are no longer visible. Bottom row: as with top row but with non-contrasting colours. Diagram by the author.

We must, however, ask the question of whether Pointillists actually intended their brush strokes to mix optically. Given the confused nature of the writing of the Pointillists, and the conflicting information from their paintings, it is not easy to judge this. Certainly, many Pointillist paintings contain brush strokes that are clearly visible, implying that optical mixture was not the intention.

Notably, Signac's late paintings, such as *Antibes, Evening* (1914), are painted with such large brush strokes that it is difficult to believe that he wanted optical mixture to occur. However, he had written quite emphatically:

> by the optical blending of these pure colours, and by their varying proportions, they [the Neo-Impressionists] obtained an infinite quantity of colours, from the most intense to the most grey.

(Signac, 1899 (Editied version: 1964; Trans: 2003), p. 16)

It might be illustrative to compare paintings Signac produced before the above quote, such as *Comblat le Chateau. Le Pré* (1886), with later paintings such as *Antibes, Evening* (1914). His 'veil of grey' quote showed that he must have become aware that there was something wrong with the theory that optical mixing produces brighter colours, causing him to increase the size of his brush strokes. We can conclude that the increased size of Signac's brush strokes was intended to produce a more lively finish, and that this would indeed occur.

We might, then, argue that what was important in Pointillism was the shimmering effect the dots gave the paintings, as well as the compositional benefits to an organised approach to broken colour. Gage provides some further evidence on this when he notes how Seurat added Pointillist dots to the back of the central bather of his 1884 *Bathers at Asnières*:

> The retouchings in bright blue and orange on the back of the central bather fuse at a distance to a warm bluish-pink, which is very close to the original palette-mixed shadows under his arm. It seems clear that Seurat was not so much interested in the optically-mixed tone as in the lively texture created by the separated dots themselves.

(Gage, 1987, p. 452)

A consequence of optical mixing not occurring is that it becomes possible that Pointillists could use simultaneous contrast in their matrices of brush strokes. This is illustrated by the image second to the top left of Figure 87 (p. 234). The brush strokes are clearly visible, so the contrast effect still works. Furthermore, the ratio of the total length of the boundaries between the areas and the areas themselves is increased, so more of the contrast effect can occur.

This effect can be seen in the building on the upper right of Seurat's 1888 *Port-en-Bessin* (Minneapolis Institute of Arts). Even from a fair distance, the matrix of blue and orange dots that make up the building is clearly visible, thus allowing simultaneous contrast to occur. As with the top left of Figure 87 (p. 234), the colours in the matrix appear stronger and more vibrant due to the small size of the dots, but the colours do not fade away into a 'veil of grey', because the dots are still visible.

The point that the brush strokes of Pointillist paintings often do not optically mix leaves us with the question noted at the beginning of this section of how objects depicted by Pointillists can be perceived as objects, and not just an array of brush strokes. This question does not only concern Pointillism. In mosaics, the tesserae are often large enough to see quite clearly, even when standing some distance away. Despite this, we perceive mosaics and Pointillist paintings as depicting the objects they were intended to depict. Pointillist paintings and mosaics can be read at two levels: as points and tesserae on one level, and Parisian pleasure seekers and Roman gods on another.

The theory of scales can be used to explain this. A Pointillist painting is processed by the visual system into a number of different scales. This includes a general level and a more detailed level. We might observe that Pointillist paintings and mosaics, being made of two conflicting scales, are similar to the pixelated image of the peahen we saw earlier (Figure 75, p. 214). The visual system separates out the two levels, and as a consequence the array of brush strokes that form the image are not perceived by the visual system as the details of the image. Normally, the visual system's decomposition of an image, as seen in Figure 71 (p. 211), produces two different aspects of the same image. With a Pointillist painting, however, one level of the decomposition has information about the objects depicted, and the other is an abstract matrix of brush strokes. The viewer is thus kept in a state of tension: the image is seen as both an array of brush strokes and the objects depicted.

In conclusion, we might summarise the elements of Pointillism here, beginning with its motivations, which might be said to be: to create a lively surface, simultaneous contrast in paintings with larger brush strokes, and the compositional approach of breaking down a scene into visual components.

We might also delineate the theoretical components of Pointillism, and the results of our analyses of them. Firstly, there is the notion of optical mixing. As we have noted, this occurs in many Pointillist paintings. When used in painting, optical mixing tends to lead to paintings having a 'veil of grey', or in other words washed-out pastel colours; a possible disadvantage. Secondly, there is the issue of simultaneous contrast. As we saw, this cannot occur simultaneously with optical mixing, but can occur in Pointillist paintings if the brush strokes are large enough. Thirdly, there is the related issue of the size of Pointillist brush strokes, namely that if the brush strokes are visible we should perceive a painting as an array of brush strokes and not as a depiction of objects. In the next section we will see how the theory of scales can explain this phenomenon.

SEURAT

We will now examine how the theory of scales can be used to analyse Pointillism in more depth. For example, scales can be used to explain why Pointillists, and Seurat in particular, used a variety of different sized brush strokes. Seurat varied significantly the size of brush strokes in any one painting. Gage notes a possible explanation for this, namely that different colours optically mix at different distances, and as a result need to be painted at different sizes so they will mix when viewed at the same distance. Gage notes a criticism of this theory. He argues that Seurat's dot sizes do not actually correspond to the sizes needed for optical mixture. Gage argues that Seurat could not have tested optical mixture very thoroughly, and it is thus unlikely that smooth optical mixture was of any real importance to him (Gage, 1987, p. 452). Furthermore, the idea that the variation of dot size could be of importance in optical mixing seems to contradict the fact that the pixels of television screens do not vary in size, and yet consistent optical mixing appears to occur.

In order to find the reason for Seurat's different sized brush strokes, we will consider Seurat's 1888 *Grey weather, Grande Jatte* (Philadelphia Museum of Art). We might begin by noting the specific variation of dot size in the painting. The small boat to the right of the central boat is made up of larger brush strokes than both the bush and tree in front of it and the boat to the left (Figure 88 (p. 238), Figure 89 (p. 239)).

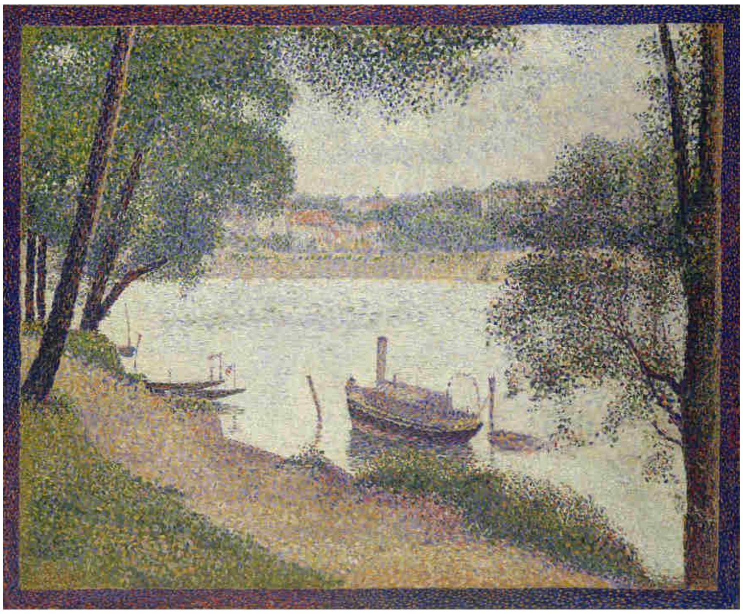

Figure 88 Georges Seurat. *Grey weather, Grande Jatte.* 1888. Philadelphia: Philadelphia Museum of Art.

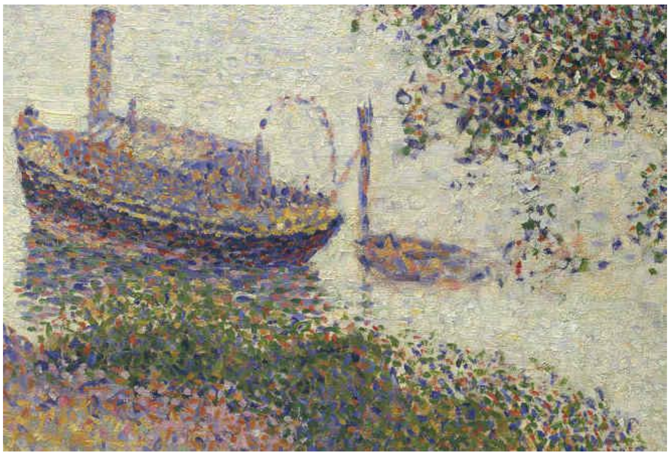

Figure 89 Georges Seurat. *Grey weather, Grande Jatte.* 1888. Philadelphia: Philadelphia Museum of Art. (Detail.)

What is the reason for the different sizes of these brush strokes? We might consider three hypotheses. The first possibility is the theory mentioned above that Seurat used different sized brush strokes so the optical mixture would occur evenly. That this is not the reason for the different sized brush strokes can be seen if we observe that the right-hand boat and the top of the left-hand boat are made of the same colours, but have different sized brush strokes.

The second possibility is that the brush strokes in the right-hand boat in the background are painted larger to situate spatially the boat behind the bush in the foreground, by reducing the amount of detail in objects further in the background. This seemingly corresponds to the idea that as objects recede into the distance, the detail the viewer sees decreases. However, if we look more closely at Figure 89 (p. 239), we see that the brush strokes on the right-hand boat are smaller than the brush strokes on the funnel of the left-hand boat, despite the right-hand boat being closer to the viewer in terms of depicted space than the funnel of the left-hand boat.

This lack of correlation between the sizes of brush strokes and distance perception is consistent with psychological experiments. Researchers have shown that scale perception occurs in the visual system before depth is perceived (Oliva & Schyns, 1997) (Marshall, Burbeck, Ariely, Rolland, & Martin, 1996). The visual system would thus resolve the brush strokes in a Pointillist painting into objects before it situates those objects in space. We can thus conclude that there is no evidence to think that Seurat intended that the size of the brush strokes would aid the depiction of depth in Pointillism.

We can see the inconsistency between the sizes of brush strokes and spatial depiction in the work of other Pointillists, such as Henri Delavallée (1862–1943). In his 1887 *La Rue au Soleil à Port-Manech* (Figure 90, p. 241), Delavallée uses a range of different sized strokes, and these do not correlate with pictorial distance. Starting in the distance and coming forward, we might note that the sky has large brush strokes, the trees in the distance have small brush strokes, the grass in the middle distance on the left have medium-sized brush strokes, the bushes in the middle distance to the left of the path have small brush strokes, and the brush strokes on the rocks in the foreground are very large.

Figure 90 **Henri Delavallée. *La Rue au Soleil à Port-Manech*. c.1887.**

Why, then, did Seurat paint the right-hand boat with larger brush strokes? Experiments by Oliva and Schyns show that the visual system's perception of scales is a top-down process that attempts to recognise objects. They examined how the visual system uses the information associated with different scales. They discovered that the visual system actively uses the differences in the scales available from any stimulus to help identify objects (Oliva & Schyns, 1997).

We might note that the right-hand boat is very close to the tree on the far right. Using different sizes of brush strokes allows the tree to be clearly distinguished as a separate object from the boat, whereas without the difference in dot size the tree and the boat would appear to merge. We see this merging happening with the tree and the far bank of the river, but here Seurat distinguishes the bank from the tree by the bank's extension far to the left of the tree. Lacking such an extension, the little boat would be visually swamped by the tree. We can thus conclude that Seurat intuitively used scales in the form of dot sizes for the purpose of differentiating objects.

Another example outside of Pointillism proper can be seen in Édouard Vuillard's 1893 *Interior of the Work-Table*. The woman at the front is primarily distinguished from the patterned wall paper by the different sizes of the brush strokes of her dress and the wall paper. Again, we should note that Vuillard would have known no theory of this idea, but was aware of this phenomenon intuitively: psychologists describe what we intuitively know, but might not have described precisely before. We saw this in the *Introduction* section 'Art and Perception' (p. 18), where we saw that the sun can be painted with the same paint as moonlight. We saw there that vision science was able to provide a precise description of this (in that case that there is a logarithmic scale between perceived and actual light). We see that vision science provides a similar description with scales.

Vuillard spent much of his career playing with the way the patterns on objects can provide object recognition, intuitively playing with the effects of scale on recognition. In his 1895 *The Dressing Table* he pushes the possibilities of pattern in object recognition to their limits. The flowers are recognisable from the floral wallpaper mainly by the difference in the dot size and notably the way the background is more blurry. This is similar to the hybrid stimulus of Figure 91 (p. 243), which is of the type investigated by Oliva and Schyns. In *The Dressing Table* the low frequency is the wallpaper background, and the high frequency is the collection of flowers; while in this picture the blurry frequency is that of a city, and the high frequency is a motorway. A similar effect can be seen with the woman's dress and the wallpaper in *Portrait of the Artist's Mother and Sister in the Studio* (1891).

Figure 91 'This figure (adapted from (Schyns & Oliva, 1994)) shows an example of a hybrid stimulus used in our experiments. The picture mixes the fine information (High Spatial Frequencies) of a highway with the coarse information (Low Spatial Frequencies) of a city. To perceive the city in Low Spatial Frequencies, squint, blink, defocus, or step back from the picture. Hybrid stimuli (see (Schyns & Oliva, 1994)) are unique because they multiplex information in scale space.' (Oliva & Schyns, 1997).

CONCLUSION: SCALES AND THE THEORY OF ART

Let us again return to the theory of art as we left it in *Chapter 2* (p. 161), namely that a picture may leave out certain features of a subject matter, and modify or distort others. The features chosen by the artist provides the information about the subject matter that the artist feels is relevant. The modifications and distortions either aid the presentation, or distort the subject matter.

The theory of scales presents us with experimental examples of four processes in perception that are relevant to depiction: decomposition, distortion and filtering, and recomposition.

Firstly, the theory of scales allowed us to examine the processes of decomposition and recomposition. We noted that Vuillard understood this process intuitively, and played with its effects, making the patterns of objects the only way they can be differentiated. We can note that this highlights the need for the visual system to decompose visual stimuli into scales in order to facilitate object recognition.

Secondly, the theory of scales allowed us to examine the process of distortion. We saw how the perceptual system can allow us to make sense of pictures that do not resemble reality in all respects, and that contain information that contradicts resemblance. In the example of the Duccio we saw the visual system's division of the cloth into different features, one being the modelling and the other being the pattern. This caused the visual system not to detect the fact that the pattern of the cloth does not appear to fold and bend across the surface of the cloth as it would in reality.

This is a key point in depiction. If we consider most pictures, they do not really resemble reality that much. The figures in, say, a Duccio or a humorous cartoon would be quite shocking to us if we met them in real life and they looked as they do in the picture in question. (Although some artists may disagree, as in Figure 92 (p. 244).)

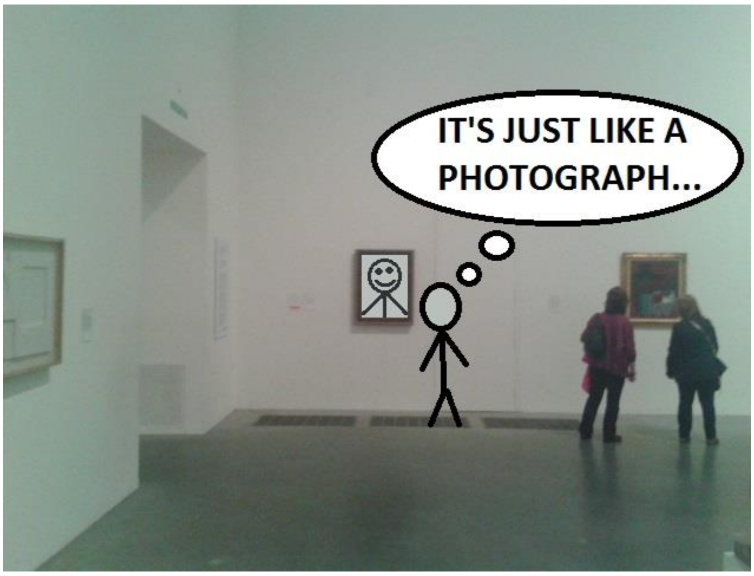

Figure 92 'It's just like a photograph…' Cartoon by the author.

Despite this, we are able to recognise a stick figure as a figure, even though as a depiction it clearly modifies its visual presentation. The theory of scales provides an example of the sort of psychological mechanisms that permit such a distortion.

Thirdly, the theory of scales allowed us to examine the process of filtering. We noted above that a cat can see fine details that we cannot, while we can see broader details not visible to a cat. Scales provides an example of how the visual system filters out some information. Hence the theory of scales provides an example of why a picture does not have to contain all the information from the view of the subject, or more precisely, why it does not have to send the entire array of light that the subject matter itself would. Imagine, for example, we look at a mouse. The tips of the whiskers would send light into the pupil, but due to the human visual system's inability to detect that scale of detail, the whisker tips would be invisible to us. An artist would therefore not have to paint the whisker tips, and yet the painting might still be said to resemble the mouse.

We might note, however, that an artist does not have to include all the features of a mouse in a picture, even those the viewer would normally detect. A line drawing of a mouse would readily be identifiable as being of a mouse, but might not have any colour in it, even though we normally would see the grey of a mouse's fur. We will examine this problem of how we would recognise such an image of a mouse in the next section.

DECOMPOSITION AND RECOMPOSITION: RECEPTIVE FIELDS (APPLICATION OF PSYCHOLOGY TO ART 6)

Up to now in this chapter we have seen how the visual system decomposes a stimulus into component features, processes these features, and recombines them. We now need to examine a problem suggested by outline drawings that can be solved using the notion of visual decomposition.

Such drawings have an unusual property in that because they delineate the boundaries of objects but contain no 'fill-in', or details of anything between the outlines. An example of this can be seen in the section 'Teaching how to draw people' in the early-Qing Dynasty book 芥子園畫傳 *(Manual of the Mustard Seed Garden)*.

We have seen that the visual system detects the edges of objects, but that we would still normally see that which is between the edges, and thus the objects in line drawings should be unrecognisable. In this section we will see why this is not the case.

We might begin by delineating three important properties of the visual system relating to the topic of receptive fields. The first of these properties is that of the *receptive field* itself. As we saw earlier when discussing trichromacy theory, it had long been known that the retina, the light detecting area of the eye, is made up of light detecting cells known as 'photoreceptors'. Eventually, however, it became clear to researchers that while this is true there is a complication: each V1 brain cell responds to signals from a collection of adjacent photoreceptors, rather than to an individual photoreceptor. The area of the retina processed by a brain cell is known as that cell's 'receptive field'. These receptive fields are represented by Figure 93 (p. 247), where the large circle represents the retina, and the smaller areas represent the receptive fields of individual brain cells. This figure is merely for illustration; in reality there are a huge number of receptive fields, which overlap. Furthermore, the processing of the retinal signals involves a complex aggregation process whereby signals from multiple receptive fields are combined and processed by the brain (Clay Reid & Martin Usrey, 2013, p. 577). While it is important to recognise this complexity, the simplified scheme outlined above is adequate for our needs here.

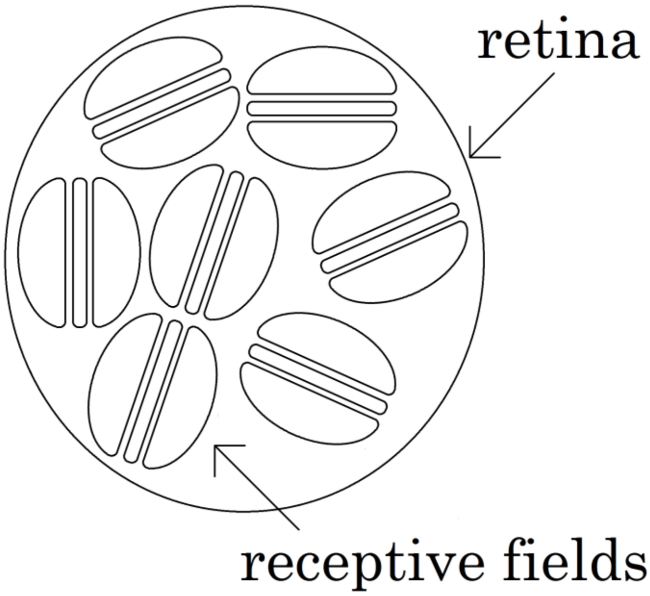

Figure 93 Diagram illustrating the areas of a cat's retina that stimulate 'V1' brain areas. Diagram by the author.

The second of these properties is the fact that the visual system detects boundaries rather than points or areas of light. This occurs in the area that performs the initial visual processing, namely the V1 area that we saw earlier, located at the back of the head. The workings of V1 were investigated in the 1950s by neurobiological researchers Hubel and Wiesel. In these experiments Hubel and Wiesel discovered the first of three ideas that are of importance to us here, namely that the V1 area is responsive to lines, and notably edges and thus contrast, rather than points or areas of light (Hubel & Wiesel, 1959).

The third of these properties is the division of the information about vision into 'channels' in the visual system. We saw earlier in the section 'Colour

Vision—Cones and Rods, What and Where' (p. 111) that the visual system is divided up into two subsystems, the 'what' and the 'where', and that the 'what' subsystem is divided into two further subsystems, 'colour' and 'form'. These two sub-subsystems have different levels of acuity, due to the properties of their receptive fields. Experiments have shown that the V1 cells are divided into those that deal with brightness-contrast and those that deal with hue-contrast, sometimes known as the 'form' and 'colour' subsystems (Hubel & Wiesel, 1959, pp. 574–591) (Gouras, 2009).

To begin our analysis we might note firstly that the hue-contrast detecting cells have large receptive fields in comparison to the brightness-contrast detecting cells, leading to the hue-contrast detecting cells being low resolution. This is because a receptive field aggregates all the stimulation from the rays of light that fall on it into one signal. As a result most of the detail provided by the rays of light is lost. In contrast, the brightness detecting cells have small receptive fields, and are thus high resolution (Livingstone M. , 2002, p. 165).

We might develop this by noting the traditional subdivision of Renaissance art into *disegno* and *colore*, exemplified by the opposition of the Florentine art of Michelangelo and Leonardo to Venetian art (Riley, 1995, p. 36). The lines in drawings such as those by Leonardo do not have variations in hue, and are thus perceived using the brightness-V1 cells. Titian's paintings, however, involve much variation of hue, and thus have the involvement of the hue-V1 cells. As a result of mainly being perceived by the brightness-V1 cells, with their high resolution, Leonardo's drawings can involve fine details. Titian's paintings, on the other hand, are primarily perceived by the low resolution hue-V1 cells. As Titian was not so interested in line and drawing, but was instead interested in colour, there was no need for so much detail, as the colour cells would not detect the fine details. This can be seen in by comparing the lips of the god in Titian's 1520–1523 *Bacchus and Ariadne*, composed of three areas of subtly varying red hues with little fine line delineation, with the lips of the figures of the Sistine Chapel, whose details such as the philtral ridge are finely delineated. It is of course true that highly detailed colour pictures can be produced, but there will always be less potential, and furthermore less need, for detail than if the picture was done in black and white. We see that Titian was primarily interested in colour, and thus detail was less important to him as our ability to detect detail in colour is less.

Figure 94 Titian. *Bacchus and Ariadne.* 1520–1523. London: National Gallery.

What is of particular interest to us here is that two features of vision detected by the visual system, namely form and colour, are split up in the brain. More importantly, these two features can be processed separately, and due to the decompositional properties of the visual system can be perceived differently.

In conclusion we might note that with the theory of receptive fields we see more evidence that the visual system divides information up into what we have called features. Furthermore, we have seen in this section that the visual system is capable of processing these features separately, and that the viewer is capable of perceiving features separately, explaining how artists are able to produce forms of art such as outline drawings. We now need to move on to examine in further depth why artists choose to include, leave out, or possibly distort particular features in pictures.

THE SELECTION OF FEATURES IN THE CREATION OF PICTURES: PERSPECTIVE, CROSS-CULTURAL PSYCHOLOGY, AND THE PERIOD EYE (APPLICATION OF PSYCHOLOGY TO ART 7)

INTRODUCTION

> I found myself … on a high hill … With me was a Pygmy youth, named Kenge … Kenge was then about 22 yr. old, and had never before seen a view such as this … Kenge looked over the plains and down to where a herd of about a hundred buffalo were grazing some miles away. He asked me what kind of insects they were, and I told him they were buffalo, twice as big as the forest buffalo known to him. He laughed loudly and told me not to tell such stupid stories.

(Turnbull, Some observations regarding the experiences and behaviour of the BaMbuti Pygmies, 1961, pp. 304–305), quoted in (Phillips W. , 2011, p. 160)

We saw in the section ‘Against Simple Resemblance: Saccades, Screen Colours, Screen Resolution, and the Cornsweet Illusion (Application of Psychology to Art 1)’ of *Chapter 1* (p. 81) that the visual system does not distort our view of space, so we can be confident that linear perspective provides a way of depicting space as we see it. However, we still need to examine how each of us comes to know about distance ‘cues’, such as relative size and converging lines. Are we born with the knowledge that objects look smaller in the distance, and that converging lines are a feature of increasing distance, or do we have to learn this from experience? The above story about the boy Kenge would seem to imply that it is a learned trait, but due to its anecdotal nature makes the above quote somewhat unreliable. As a result we will need to examine this in greater detail.

The section is divided into five subsections. 'Perspective: Lines, Convergence, and Intersection' (p. 251) brings together our understanding of how the visual systems firstly detects lines and line intersections, then attempts to interpret them. This summary lays the groundwork for the psychological understanding of the depiction of space. 'Cross-Cultural Psychology—Perspective and Culture' (p. 255) presents one way to understand how spatial depiction varies in culture, namely the use of experimental psychology. 'Cross-Cultural Psychology—The Müller-Lyer and Ponzo Illusions' (p. 260) analyses specific examples of how the depiction of space has been examined across cultures. 'Cross-Cultural Psychology—Summary' (p. 265) argues for the pros and cons of this approach. Finally, 'The Period Eye' (p. 266) presents another approach, namely the method of the period eye, developed by Baxandall. Though this method is historical and not experimental science, we will see how we can combine it with the experimental science of cross-cultural psychology to provide a more powerful approach.

PERSPECTIVE: LINES, CONVERGENCE, AND INTERSECTION

In previous chapters we examined linear perspective and vertices. We saw that a viewer detects the boundaries of areas of colour and tone in the light that enters the pupil. These boundaries have relative direction, and intersect. It will be useful now to summarise this process.

The process can be said to be: *detecting edges*, *detecting and interpreting their relative direction*, *and detecting and interpreting their intersections*. Consider what happens when a viewer sees Figure 95 (p. 253).

The visual system will begin by *detecting the boundaries* between areas of hue and tone, as analysed in the section 'The Visual System' of the *Introduction* (p. 49) (Figure 96, p. 253). This stage forms the basis for the other stages.

The visual system then does two things. The first of these is *detection and interpretation of the relative direction of these lines* (Figure 97, p. 253, Figure 98, p. 254, and Figure 99, p. 254). These converging lines are perspective lines, and are one of the main ways that the visual system judges how far an object is away from the viewer. As the lines in any of the above sets get closer, the object appears to recede away from the viewer. As we saw in *Chapter 1* (p. 65), the rules of linear perspective, developed in the Renaissance by artists such as Brunelleschi, allow us to depict such lines in a way that resembles reality. Linear perspective creates lifelike depictions of receding lines, as we saw with Figure 8 (p. 73), and furthermore allows the artist to situate objects in pictorial space that mimics the visual system's processes of judging the distance of objects from the viewer.

The secondly of these is the *detection and interpretation of the intersection of these lines*, which we met in *Chapter 2* (p. 161). We saw that the vertices can be interpreted as the T-, Y-, and arrow-vertices described by recognition-by-components theory (Figure 100, p. 254).

Figure 95 Stone steps. Photograph by the author.

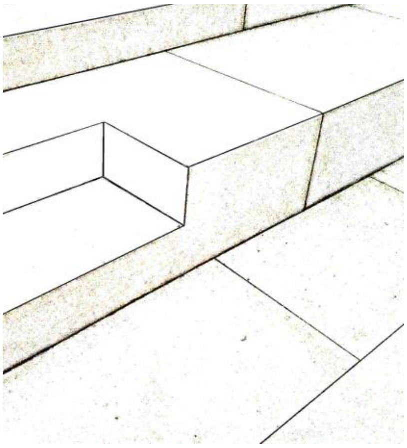

Figure 96 Stone steps. Boundaries. Photograph and processing by the author.

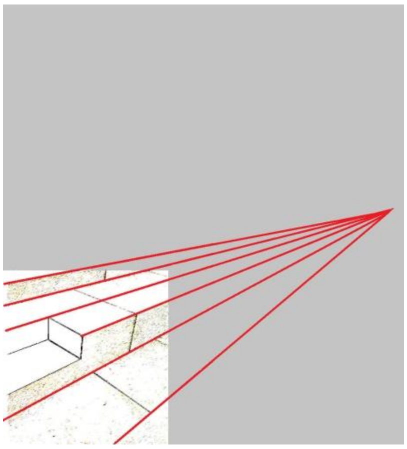

Figure 97 Stone steps. Converging lines 1. Photograph, processing and diagram by the author.

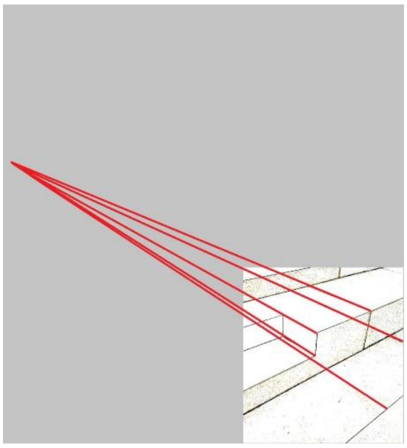

Figure 98 Stone steps. Converging lines 2. Photograph, processing and diagram by the author.

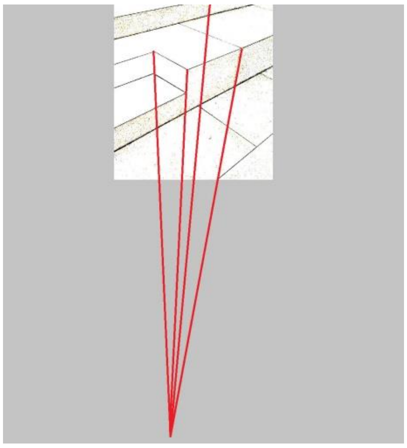

Figure 99 Stone steps. Converging lines 3. Photograph, processing and diagram by the author.

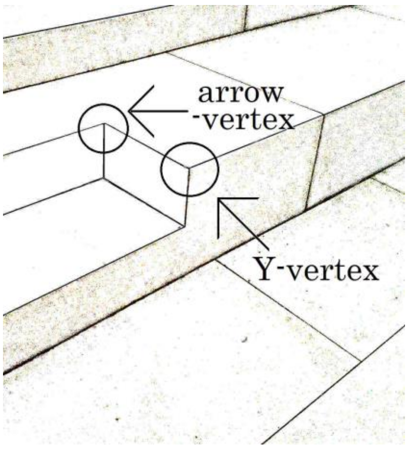

Figure 100 Stone steps. Some recognition-by-components interpretations of line intersections given. Photograph, processing and diagram by the author.

CROSS-CULTURAL PSYCHOLOGY—PERSPECTIVE AND CULTURE

Armed with this knowledge, we can proceed to examine our two ways of understanding the effect culture has on the depiction of space, namely cross-cultural psychology, and the technique of the period eye. We will begin with cross-cultural psychology.

The interpretation by the visual system of converging lines as parallel lines in space might, at first glance, appear to be something that would be true of all humans, regardless of culture. We saw in the section 'Against Simple Resemblance: Saccades, Screen Colours, Screen Resolution, and the Cornsweet Illusion (Application of Psychology to Art 1)' of *Chapter 1* (p. 81) that Panofsky doubted this, and proposed that the retina distorts human perception of parallel lines, but that the culture of the Renaissance caused the creation of paintings that attempted to overcome this. We also saw, though, that Panofsky was wrong in his theory, and the retina's distortion of the array of light that hits it does not affect the perception of the array of light that hits it.

The idea that culture can affect human perception is, however, intriguing. Art historian Michael Baxandall theorised about this problem:

> An object reflects a pattern of light on to the eye. The light enters the eye through the pupil, is gathered by the lens, and thrown on the screen at the back of the eye, the retina. On the retina is a network of nerve fibres which pass the light through a system of cells to several million receptors, the cones. The cones are sensitive both to light and to colour, and they respond by carrying information about light and colour to the brain.

> It is at this point that human equipment for visual perception ceases to be uniform, from one man to the next …
>
> (Baxandall, 1972, p. 29)

We saw that the retina does not distort our perception of space, but what of the rest of the visual system? Does the visual system interpret converging lines in the same way for all humans, or does it vary across cultures?

Furthermore, and most importantly for this thesis, we need to ask how this relates to depiction; different cultures depict in different ways, and most do not use the realistic form of depiction linear perspective provides, as we saw earlier in the subsection ‘Non-Resembling Depictions of Space’ of the section ‘Against Simple Resemblance: Saccades, Screen Colours, Screen Resolution, and the Cornsweet Illusion (Application of Psychology to Art 1)’ of *Chapter 1* (p. 90).

Consider studies into the perception of depth found in different cultures (Phillips W. , 2011, pp. 168–173). Philips gives an example of a 1974 study by Jahoda and McGurk of testing linear perspective drawings on groups of children (Jahoda & McGurk, 1974). Jahoda and McGurk studied four groups of children at school age: a group of schoolchildren from Glasgow, a group of children from rural villages in Rhodesia with little formal education, a group of schoolchildren from Hong Kong, and a group of children from Hong Kong with little formal education. By using these four groups Jahoda and McGurk were able to test the perception of perspective as it differs against two variables: formal education (the schoolchildren from Hong Kong, against the children with little formal education from Hong Kong), and living in an urban environment (the schoolchildren from Glasgow and the schoolchildren from Hong Kong, against the children with little formal education from Hong Kong, and the children with little formal education from rural villages in Rhodesia). The researchers also subdivided the groups into age, so as to test for a third variable.

Jahoda and McGurk used pictures that included converging straight lines and variations in the size of objects to depict perspective. They showed these pictures to the participants to judge their perceptions of the space in the pictures. The researchers made a number of discoveries. The urban groups made better size judgements overall, indicating that living in an urban environment helps to give children a better understanding of this particular aspect of space. A less powerful piece of evidence in favour of this can be found in the discovery that both the schooled and unschooled Hong Kong children made better spatial judgements than the Scottish or Rhodesian children. This might indicate something specific in Hong Kong culture, or perhaps the effect of the heavily built up Hong Kong environment.

Both the Scottish children (urban and schooled) and the Rhodesian children (non-urban and unschooled) improved with age with both size judgements and spatial relationships, indicating that understanding of perspective increases with age regardless of environment or education. It would seem, however, that culture can play a complex role in age development as well. In neither of the Hong Kong groups did age affect size judgement, and age only improved spatial understanding with the schooled Hong Kong children, not the unschooled, again indicating the complex interactions of the variables of age, environment, culture, and schooling (Phillips W. , 2011, pp. 168–173).

Psychological phenomena are problematic to study because it is not normally clear whether the cause of a particular phenomenon is the individual, genes common to the species, or environmental variables such as culture. The cross-cultural psychological approach allows the controlling of individual and cultural variables to allow the researcher to discover what is common to all humans, and involves performing experiments on subjects from two or more cultures, in order to test the differences and similarities between them.

Though this sounds an ideal way to learn about culture, there is an obvious problem, namely the difficulty of actually collecting such data. How, for example, does the experimenter into perceptions of spatial depiction find enough different cultures, with different perceptions of space, uncontaminated from the others in a very connected modern world? We shall see some of the difficulties faced, how these can be overcome, and what the limitations and possibilities of this approach are.

Before looking at general conclusions of how cultural variations of perceptions of depth have been studied by cross-cultural psychologists, it will be of use to examine their methodology in more detail. A cursory glance at cross-cultural psychology implies that it is the ideal way of identifying the cultural variables and psychological constants in human interpretation of images; however, as Keith points out the situation is not quite that simple (Keith, 2011, p. 9). Keith argues that attempting to maintain culture as an independent variable, while controlling other variables, could lead to the 'failure to identify specific aspects of culture that may influence dependent measures'. The experiments mentioned above present a ready example of this: the similarity of the schooled and unschooled Hong Kong children came as a surprise to the investigators.

This indicated how slippery the data can be; without the Hong Kong data it would not have been apparent that there is a separate cultural variable that acts on spatial judgements and not on size difference. Further experiments indicated that this similarity between schooled and unschooled children might not have occurred in other cultures, indicating the difficulty of controlling experiments (Phillips W. , 2011, pp. 173–177).

We shall now draw some conclusions from cross-cultural psychology about the perception and depiction of space, before moving on to a more specific example. Interesting for the current discussion is that Phillips examines the perceptions of space specifically concerning pictures. Cross-cultural psychologists have studied space depicted with converging parallel lines, texture, relative size, and elevation. Phillips notes that many peoples of the world have difficulty perceiving pictures at all, even photographs; others found images highly emotive, even thinking they are real. Furthermore, familiarity of pictures in general helps recognition of pictures, as do particularities of the image, such as familiarity of the objects. People tend to prefer depictive styles they are familiar with, for example, those who are used to the 'spread-eagled' style, as shown in Figure 101 (p. 260), will tend to prefer this style over others. Education, age and urbanisation tend to make it easier to interpret depicted space, but this is only a tendency and there are variations. For example, regardless of the variations of education, age and urbanisation, children from Hong Kong have similar abilities at understanding spatial relationships, implying there is another cultural facet at work, which may that the children in general view objects in relation to each other, rather than view each object in isolation (Phillips W. , 2011, pp. 161–173).

Figure 101 Flattened picture of a bear by Tsimshian Indians of the Pacific Northwest (Deregowski, 1972).

CROSS-CULTURAL PSYCHOLOGY—THE MÜLLER-LYER AND PONZO ILLUSIONS

We can now examine more specific examples of investigating culture and perceptions of space, involving the optical illusions known as the Müller-Lyer and Ponzo illusions (Figure 104, p. 263).

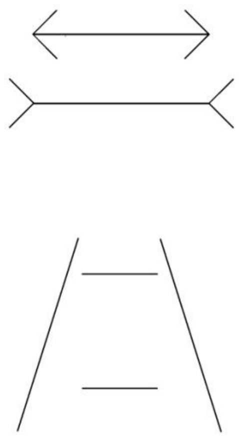

Figure 102 The Müller-Lyer illusion (top) and the Ponzo illusion (bottom). Diagram by the author.

The Müller-Lyer illusion occurs when two straight lines of equal length appear to be different lengths due to the arrangement of attached chevrons (top of Figure 102, p. 260). A hypothesis has been put forward to explain this. There is a notable similarity between the shapes of the Müller-Lyer illusion and the edges of three-dimensional cuboids. The caption to Figure 103 (p. 261) explains how this works.

Controlled experiments have shown that people who grow up in buildings with corners rather than round buildings appear indeed to be more susceptible to the illusion, giving good support to the hypothesis. An interesting addition is that children from all environments appear to be more susceptible to the illusion than adults, implying that the environment works quickly on the minds of children, yet as we grow into adults we learn to overcome the conditioning somewhat (Phillips W. , 2011, pp. 161–173).

Figure 103 The Müller-Lyer illusion. Though the illusion does not occur in this diagram, the diagram nevertheless illustrates why the illusion occurs. We perceive the long line with the arrow-chevrons (left) as longer than it actually is because the external corner is closer to the viewer. If the two long lines were the same length, the left long line would appear longer than the right long line. Photograph and diagram by the author.

The Ponzo illusion occurs when two parallel line of equal length are drawn in-between two converging lines. The parallel line nearer the convergence point of the converging lines appears to be shorter than the other parallel line, despite the lines being the same length (Figure 102, p. 260). This has been hypothesised to be a consequence similar to that of the Müller-Lyer illusion, namely due to living in a built environment. The explanation given for the Ponzo illusion is that the converging lines are similar to parallel lines at right angles to the viewing plane, and the horizontal lines are similar to parallel line parallel to the viewing plane. This illusion is often shown occurring on railway tracks, but Figure 104 (p. 263) shows that it occurs in other situations. The converging lines are like rails and the horizontal lines are like sleepers on a railroad track, or in my photo the converging lines are like the handrails of the escalator and the horizontal lines are like the steps. As the brain expects the more distant 'sleeper/step' to appear shorter, the fact that it is the same length tricks the brain into thinking it is longer.

Experiments have been performed on different groups, one consisting of people who grew up in built environments, and one consisting of people who grew up in un-built environments (Phillips W. , 2011, p. 168). Brislin, for example, tested two groups of people: one who lived in Guam, a place with few long roads, straight roads, no railways, and few open vistas; and a second group who lived in mainland United States, a place with all these features (Brislin, 1974). Brislin found that the Ponzo illusion indeed is more pronounced in people from Guam. Further studies confirmed this finding (Brislin & Keating, 1976).

The experiments on the Ponzo illusion had some interesting additional facts. Firstly, it was the built environment and not education that seemed to be the cause of the illusion, though this was not entirely conclusive; secondly, the illusion works in both pictures and three-dimensional presentations; thirdly, living in a built environment appears to cause the same effect in some other animals this does not appear to work with the Müller-Lyer illusion (Phillips W. , 2011, p. 168).

Figure 104 The Ponzo illusion. Photograph and diagram by the author.

The above leads us to the following conclusions. Firstly, as we saw in *Chapter 1* (p. 65), linear perspective provides an accurate way of drawing converging lines as they appear after passing through the pupil. Secondly, as we also saw in *Chapter 1* (p. 65), the visual system 'overrides' the curvature of the retina, allowing the viewer to see the world with straight lines rather than curvilinearly. The visual system's ability to overcome the distortion caused by the retina's curvature is at least partly due to the movement of the eye.

We will now bring together our understanding of linear perspective and recognition-by-components developed in *Chapter 2* (p. 161) with our understanding of the Ponzo and Müller-Lyer illusions. It is not difficult to see a parallel between linear perspective and recognition-by-components, and the Müller-Lyer and Ponzo illusions (Figure 105, p. 264). The chevrons of the Müller-Lyer illusion as they are perceived in buildings are recognition-by-component vertices, and the converging lines of the Ponzo illusion are the perceived as the converging lines of linear perspective. We can thus conclude that our perceptions of the converging lines of linear perspective and the vertices of recognition-by-components and to some extent at least environmentally conditioned. We will see later both how this is important, and how it relates to history.

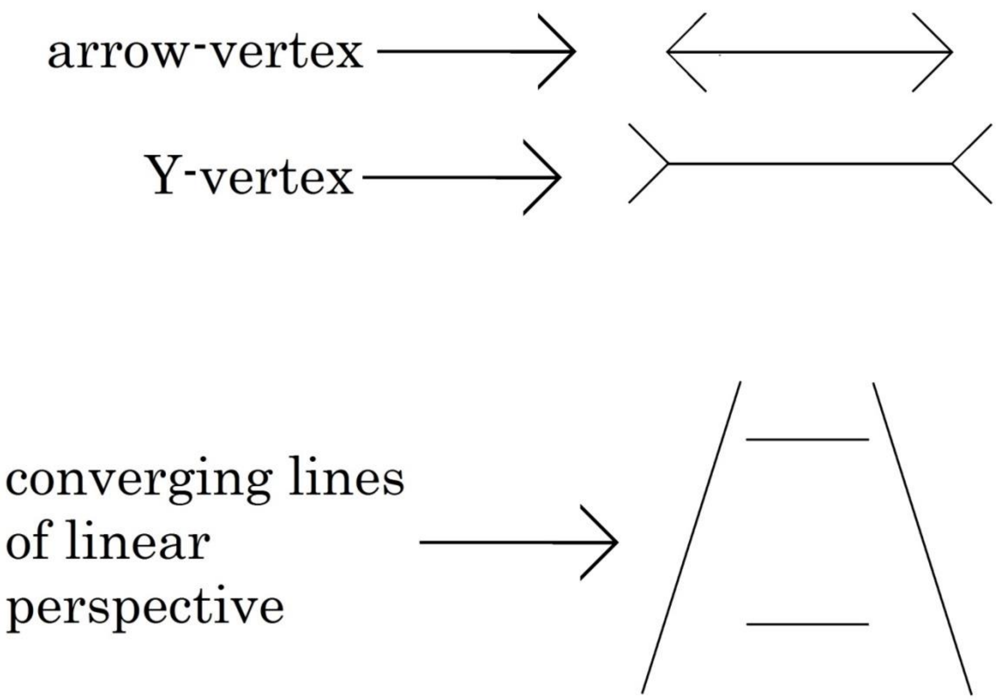

Figure 105 The Müller-Lyer illusion (top) and the Ponzo illusion (bottom) with recognition-by-components and linear perspective interpretations. Diagram by the author.

CROSS-CULTURAL PSYCHOLOGY—SUMMARY

It is thus apparent that cross-cultural psychology is in its infancy, and that though it may produce useful results, there are great difficulties in controlling variables. It should also be noted that cross-cultural psychology is limited by needing a number of different cultures to examine. In a world that is becoming increasingly homogenised by, for example, television and the internet this might become increasingly difficult. We have seen, though, that there has nevertheless been useful research done.

Cross-cultural psychologists have examined both how the brain interprets depicted space, and how the brain interprets information to recognise space in general. Cross-cultural psychologists have studied the interpretation of depicted space with 'cues' such as converging parallel lines, texture, relative size, and elevation, and both depicted space and general spatial recognition using the Müller-Lyer and the Ponzo optical illusions.

Depiction is subject to wide cultural variation; some cultures do not do it at all, some cultures attach great importance to it, and furthermore various cultures have different ways of depicting, including the depiction of space. Both familiarity of style and subject both aid correct interpretation, and are preferred by subjects. Education, age and urbanisation tend to facilitate the interpretation of depicted space, but other cultural factors, such as whether those in a culture view objects in relation to each other rather than in isolation, are of importance, in that case interpreting spatial relationships.

General spatial recognition seems to be affected by living in a built environment. It appears that children are quickly conditioned for this by their environment, but as they grow older they overcome this conditioning somewhat. The built environment appears to be more important than education, though the evidence for this is fairly weak. Also, living in a built environment appears to cause the same effect on the interpretation of space in some other animals as well as humans, but strangely only as it concerns the Ponzo illusion. This perhaps implies that humans have a greater propensity to perceive volumetric forms than other animals.

The cross-cultural experiments we have seen confirm Baxandall's point that what goes on beyond the eye in the visual system varies to some degree from person to person and culture to culture. Certainly, that cultures have developed linear perspective indicates that humans have the potential to perceive the straight and parallel lines of the world as they appear in reality, but there are definitely cultural and environmental factors in the perception of perspective. The quote we saw above by Turnbull, about the youth thinking that the buffalo were insects, is perhaps too anecdotal to treat as reliable, but as we have seen rigorous cross-cultural studies have been performed. The studies by Jahoda and McGurk, and those involving the Ponzo illusion, indicate that the perception of perspective in both images and reality is affected by a number of factors, including culture, learning and environment. This gives credence to Baxandall's argument that the perception of perspective is indeed at least partially environmentally conditioned, rather than being entirely genetic.

THE PERIOD EYE

Michael Baxandall (1933–2008) was one of the most influential art historians of the twentieth century. Born in Cardiff, South Wales, he developed a distinctive approach to the study of art history. In this subsection I will consider his notion of the period eye, also known as the theory of cognitive style. In general Baxandall's approach concerned the examination of artworks in terms of their conditions of production. He examined a broad range of these different conditions of production, including the economic constraints and opportunities of artists, the constraints and properties of the materials, such as wood, that were available to artists, and the ways that artist were either employed, or instead sold their works. The works of cultural production that Baxandall examined were diverse, and included Renaissance German wood sculpture, the paintings of Picasso, and the Forth Bridge in Scotland. From the point of view of the topic of this thesis, namely the application of human psychology to the study of art, the most important of Baxandall's approaches is the period eye, which he used in such books as the 1972 *Painting and Experience in Fifteenth-Century Italy* (Baxandall, 1972) and the 1980 *The Limewood Sculptors of Renaissance Germany* (Baxandall, 1980).

The procedure of the period eye is based on the notion that people in different cultures and periods visually perceive the world in different ways. The task of the art historian, then, is to reconstruct what caused the population of a society to perceive visually in the way they did, to delineate exactly how they perceived visually, and to examine how this affected the production of artworks. For example, Baxandall argued that in the period of the German Renaissance there was a development and propagation of three-dimensional geometry, that this caused the population to perceive the world increasingly in terms of solid three-dimensional shapes, and thus that artists incorporated such shapes into artworks.

As we saw earlier, in *Painting and Experience* Baxandall delineates one of the basic assumptions of his period eye technique. We might repeat Baxandall's comment here:

> An object reflects a pattern of light on to the eye. The light enters the eye through the pupil, is gathered by the lens, and thrown on the screen at the back of the eye, the retina. On the retina is a network of nerve fibres which pass the light through a system of cells to several million receptors, the cones. The cones are sensitive both to light and to colour, and they respond by carrying information about light and colour to the brain.
>
> It is at this point that human equipment for visual perception ceases to be uniform, from one man to the next …

(Baxandall, 1972, p. 29)

We can thus note that Baxandall assumed that the physiology of the eye is uniform across humans, and everything else that occurs with vision beyond is cultural dependent.

In order to further examine the application of the period eye technique we can examine its use in Baxandall's *The Limewood Sculptors of Renaissance Germany*. In this book Baxandall examines the wooden carvings, both freestanding and altarpieces, of the German Renaissance. He examines the whole range of conditions that affected production, including the theology of the Reformation and its varying levels of iconoclasm, the material properties of the wood used in carving, the economics of the period, and most significantly for the notion of psychology, the period eye.

In the chapter of this book on the period eye Baxandall argues that the forms of German Renaissance art were influenced by the culture of the time in a very specific way. He notes the florid style of German Renaissance sculpture, as well as the artistic production of the period in general, including calligraphy and even music. He contrasts this with the more volumetric and geometric style of contemporaneous Italian art, but argues that during the period the style of German art became more concerned with volumetric forms and three-dimensionality. What is notable to the examination of psychology is his argument of how and why this stylistic change occurred (Baxandall, 1980, pp. 143–152).

Baxandall argued that in the period before the late Renaissance, Italian schools and German schools had a significantly different curriculum. Italian schools focused on practical geometry, which they taught in order to equip their students with the skills to work within a mercantile economy. Practical geometry provides techniques, for example, to estimate the volume of a barrel of wine by using a calculation of the volume of two truncated cones. German schools, in contrast, focused on an advanced form of flourished calligraphy, the usefulness being to aid in the production of forgery-proof legal documents. Baxandall then argued that as time went on the German mercantile economy developed, and hence it became increasingly important for Germans to be educated in three-dimensional geometry, as Italians were. Hence, Baxandall argued, education in three-dimensional geometry increased in Germany.

Baxandall argued that there is a parallel between German Renaissance boys' education and the art produced; art was less volumetric in Germany than Italy while the teaching of three-dimensional geometry was neglected in Germany, then, as three-dimensional geometry became more important in German schools, volumetricity became more important in German art. Baxandall not only draws a parallel, but also goes on to delineate the mechanisms of this relationship. Firstly, Baxandall notes that the boys who received this education would grow up to be important commissioners of artworks, and also that three-dimensional geometry would have been important in the education of artists. Hence Baxandall argued that 'in a mercantile society the elementary education of boys for a business life throws a great deal of light on the common visual skills' (Baxandall, 1980, p. 147).

Baxandall delineated his proposed mechanism by which these visual skills actually propagated themselves through the visual culture. He argued that the education of German boys affected their mental development in such a way that they tended to perceive the world in a more volumetric and three-dimensional way. As a result artists produced art that catered for this view. Furthermore, the artists themselves may have been affected by the geometric education, and thus would perceive the world in this volumetric way, which would further influence the volumetric forms of their art.

We are now at a stage whereby we can begin to relate linear perspective and recognition-by-components, and the Ponzo and Müller-Lyer illusions to history. It is somewhat outside of the scope of this thesis to demonstrate the following conjecture with any rigour; the main thrust of this thesis being to present psychological arguments for the idea that pictures are arrangements of features. However, we should indicate some of the possibilities of extending the argument here.

We saw in the subsection on cross-cultural psychology that the Ponzo and Müller-Lyer illusions demonstrate that our perceptions of linear perspective and volumetric form (volumetric form being described by the vertices of recognition-by-components) are to an extent environmentally conditioned. We can see from cross-cultural psychology and Baxandall's work some of the possible mechanisms that could cause the increase in the visual system's perception of converging lines as indicators of three-dimensional space, and vertices of volumetric form.

We might thus offer the following conjecture. From the studies of the 'carpentered environment' of cross-cultural psychology we might say that the increase in buildings and carpentered objects that occurred as cities grew in the Renaissance caused Europeans to become more likely to interpret lines and line intersections as three-dimensional space and volumetric form. Furthermore, from Baxandall's studies of boys' education and the art of the Renaissance we might say that the increase and spread of the study of geometry caused the increased susceptibility of the visual system of Europeans to manifest itself in art. The population became increasingly able to discriminate features of three-dimensional space, even when not trained in art, resulting in the increasing demand for the correct construction of three-dimensional space in painting. Similar theories have been explored by art historian John Onians (Onians, 1992).

We might extend this conjecture to the theory we saw in the subsection of *Chapter 2*, 'Example 2—Wölfflin' (p. 175). We saw there that Wölfflin's idea of Classical art giving way to Baroque could be described by the notion of T-vertices of the Classical giving way to the Y- and arrow-vertices of the Baroque (Figure 60, p. 180). We might see in the above a reason for this. The T-vertices describe a way of perceiving the position of objects by occlusion. This would be the earliest way of perceiving objects, and would thus feature in the earliest paintings. As the built environment and spread of geometry in education increased, the Y- and arrow-vertices would begin to be of more importance, and a more sophisticated perception of space would take hold. The result would be Baroque spatial depiction. This process would take time however, and as a result Renaissance artists would not have had the understanding of space that later Baroque artists would, explaining the deficiency of Leonardo's *Annunciation* that we saw in *Chapter 2* (p. 161).

We should emphasise here the conjectural nature of this argument. One obvious problem is that there is no explanation of Wölfflin's theory of the cyclical nature of the Classical—Baroque—Classical—Baroque system. Why, after a clear description of form made up of all the T-, Y- and arrow vertices was achieved in the Baroque, would Classicism take hold again? Why jettison T- and Y- vertices?

Wölfflin did allude to a reason, however. He wrote:

> It is just as comprehensible that the conception of a unity of parts whose independence has been swamped in the total effect could only succeed the system with independently developed parts, that to play with the hidden adherence to rule (a-tectonic) presupposes the stage of obvious adherence to rule.

(Wölfflin, 1915, 1950, p. 229)

We might say, then, that Y- and arrow-vertices closely link objects into three-dimensional depicted space, thus causing the surrender of the objects' autonomy. This can be seen in the archetypal Neo-Classical painting, Jacques-Louis David's *The Death of Marat* (1793). This painting contains only two clear Y- or arrow-vertices, namely the two arrow vertices at the top of the box in front. We might conclude that Marat unconsciously avoided vertices in order to preserve the autonomy of the objects, notably the letter which contains the details of counter-revolutionary activity, and the box that holds the ink with which Marat might have written a reply.

CONCLUSION

In this section we have seen that the visual system detects the boundaries of objects, and interprets these boundaries as lines. The visual system then interprets converging lines as receding into the distance, and interprets line intersections as the vertices of objects.

We have seen that this process is affected by culture, and we have examined two ways of analysing these cultural influences. Firstly, there is cross-cultural psychology. For example, studies of the Müller-Lyer and Ponzo illusions demonstrate that the environment plays a role in determining our perception of visual features for distance and volumetric form.

Secondly, there is Baxandall's period eye technique. Baxandall argued that volumetric form becomes more important in art due to the increase in importance of volumetric calculation in education, making the population more aware of the notion of volume and thus volumetric depiction in art.

Culture, then, plays an important part in perception. What goes on in the visual system is not outside of culture, but is conditioned by and interacts with it. We have seen that both psychology and history can provide tools for analysing the processes involved.

CONCLUSION

In this chapter we have used vision science and psychology to analyse the consequences of the understanding of depiction that we developed at the end of *Chapter 2* (p. 161), namely that a picture may leave out certain features of a subject matter, and modify or distort others. The features chosen by the artist provides the information about the subject matter that the artist feels is relevant. The modifications and distortions either aid the presentation, or distort the subject matter.

We examined a range of mechanisms by which the visual system decomposes stimuli into its component features. For example, we saw how the visual system decomposes information into separate scales (‘Decomposition and Recomposition: Scales (Application of Psychology to Art 5)’, p. 210), into colour and brightness (‘Decomposition and Recomposition: Receptive Fields (Application of Psychology to Art 6)’, p. 245), and into lines and line intersections (‘The Selection of Features in the Creation of Pictures: Perspective, Cross-Cultural Psychology, and the Period Eye (Application of Psychology to Art 7)’, p. 250).

We also saw how the visual system’s recomposition process tends to force a coherent interpretation of visual information, which can lead to oddities in the interpretation of a stimulus. For example, we noted that the cloth in the Duccio could not in fact exist in this form in real life, for the decomposed elements do not form parts of the same object, and yet in our mind’s eye the decomposed elements recombine into a single object.

We then examined how these features of the visual system affect depiction. For example, we saw in the Dalí that the visual system identifies features of objects, such as parts of clothing and facial features, and then attempts to recombine them, but that Dalí frustrates our visual system’s attempts to form a single interpretation by presenting us with two interpretations.

We also examined the origin of the visual processes. We saw how culture affects the interpretation of lines, for example seeing how people brought up in environments without corners were less likely to interpret line intersections as the vertices of three-dimensional objects.

We might, then, conclude that the visual system decomposes the stimuli it receives from the eyes into component features, such as lines, line intersections, individual scales, hue and tone, and others. These are then interpreted by the visual system as the properties of objects, which are then recombined. Furthermore, painters exploit these features of the visual system for artistic reasons, as we saw with Duccio's sleight of hand in the cloth of the *Rucellai Madonna*. We also saw that due to the properties of the visual system objects can be recognised and thus depicted using a selection of only a few features. As a result it is possible to make pictures in forms that could not exist in real life, such as line drawings without colour.

The analysis of the recombination process has a deficiency, however. The visual system does not just recombine the features, but organises them in the mind. To form a more complete description of the visual system and the consequences the properties of the visual system have for depiction we will need to examine this organising faculty.

CHAPTER 4. ORDER: ORGANISING AND FINDING PATTERNS IN PICTURES

GESTALT CONFLICT • PATTERN RECOGNITION, AND DECORATIVE ART • SEMANTICS AND SYNTAX, AND FIGURATIVE ART

INTRODUCTION

Up to now we have been dealing mainly with recognition. This chapter examines order in art to illuminate the visual system's processes of combining information and how this affects depiction. This will explain further how the visual system recombines the information it has decomposed, and is able to find interpretations for it.

The chapter is divided into three sections. 'Conflicts in Interpretation: Gestalt Conflict (Application of Psychology to Art 8)' (p. 277) examines the issue of conflicts in the interpretation of the organisation of a stimulus by the visual system. This provides an example of way that the visual system searches for a coherent interpretation of a stimulus, thus helping to explain how the visual system can allow us to accept inconsistencies in visual information. 'Pattern Recognition, and Decorative Art (Application of Psychology to Art 9)' (p. 294) examines the abstract ordering of objects. 'Semantics and Syntax, and Figurative Art (Application of Psychology to Art 10)' (p. 305) examines the figurative features of order, and how object recognition processes and pattern recognition combine.

CONFLICTS IN INTERPRETATION: GESTALT CONFLICT (APPLICATION OF PSYCHOLOGY TO ART 8)

INTRODUCTION

The main thrust of this thesis concerns figurative art, but it will be illuminating here to examine how the sort of mental processes we have been looking at apply to the abstract and organisational elements of art. In the last section, we used the theory of scales to see how the visual system deals with contradictory information in recognition processes, and how artists either cope with, or indeed exploit, such mental properties. We saw, for example, that the visual system allows us to perceive the background of the Duccio as a single woven cloth, even though the pattern makes the cloth appear flat while the tonal modelling makes the cloth appear to have folds. In this section, we will move away from the problems of object identification and instead examine the way that the visual system deals with contradictory information in the perception of visual order in a broader sense.

For example, consider Francisco de Zurbarán's painting *Still Life with Lemons, Oranges and a Rose* (1633). We might ask ourselves the question of how Zurbarán arranged the composition, and will see in this section that visual psychology can help us to answer such questions. We might note that we first perceive the objects as arranged by proximity into three equidistant groups. After a while, however, we note that the colours imply a different arrangement: the lemons and oranges 'pull' together to form one group, while the white cup on the right joins with the flowers above the oranges, and the pink flower is affected by both distance and colour to separate itself off on its own. Visual psychology thus allows us to explain an element of Zurbarán's compositional technique. Furthermore, we will be able to answer another question, namely that by examining how these processes of grouping work we can discover how the visual system's attempts to find a coherent interpretation of a stimulus is not a property only of the object-recognition subsystem, but is a more general property of the visual system. This will allow us to find a link between the object-recognition and organisational systems, which will allow us to explain features of art such as impossible figures, as well as forming a better understanding of general principles of perception.

The section is divided into two subsections. 'Gestalt' (p. 278) provides an overview of the theory of gestalt. 'Gestalt Conflict' (p. 284) moves onto the particular aspect of gestalt that is of relevance here, namely what happens when the elements of perceived order are in conflict, concluding with an argument concerning how this relates to the theory of art that we have been developing.

GESTALT

The main theory of perceptual organisation developed by psychologists is that of *gestalt*, whose name is taken from the German for 'shape' or 'form'. Gestalt psychology began just before World War 1 by three German psychologists, Max Wertheimer (1880–1943), Kurt Koffka (1886–1941), and Wolfgang Köhler (1887–1967). The gestaltists argued that it is the interrelationships between objects that are of importance, rather than the individual objects themselves. The gestaltists would often point out that a melody is the same regardless of the key in which it is played; it is the overall effect of the relationships between the notes that matter. This principle is often summarised by the statement that 'the whole is something else than the sum of the parts', sometimes stated as 'the whole is more than the sum of the parts' (Koffka, 1935, p. 176). Koffka defines gestalt by analogy with sociology; a gestalt is a group of objects, just as a property of humans may define a group of people:

> A sociological group, then, has existence, in the sense in which a gestalt has existence, and since the criterion we have used for the reality of the group is at the same time a criterion of its gestalt character, we must infer that a group is a gestalt.
>
> (Koffka, 1935, p. 649)

Such properties identified by the gestaltists that define gestalts include similar shape and size. The work of the gestaltists is thus of great importance as we move the discussion from the identification of objects into the ordering of objects (Behrens, 1998).

Despite the obvious relevance of this to the study not only of perception but of art, gestalt theories have been criticised by both writers on art and psychologists, most notably for us here by Gombrich. Gombrich's criticism relates to an issue noted in the section 'The Conflicting Ideologies of Colour' of *Chapter 1* (p. 146), namely that of nativism/empiricism debate. Gestalt psychology favours nativist, or 'top down' approaches, while Gombrich favoured 'bottom up', or empirical approaches. Gestalt psychology proposes that the visual system searches objects for pre-determined patterns, such as similarity of shape or colour, while Gombrich argued that the visual system searches for information, and uses this information to analyse visual patterns (Gombrich, 1979, p. 121).

Indeed, it should be noted that gestalt processes can be said to play only one role among others in perceptual organisation (Eysenck & Keane, 2010,

p. 82) (Kimchi & Hadad, 2002). However, recent experiments have confirmed that gestalt does indeed play an important role in perception (Blake & Sekuler, 2006, p. 184). Experiments have shown, though, that gestalt is of particular importance in the perception of artificial figures, such as textile patterns, rather than in natural figures, such as rivers (Eysenck & Keane, 2010, pp. 80–85) (Pomerantz, 1981) (Geisler, Perry, Super, & Gallogly, 2001) (Elder & Goldberg, 2002). That gestalt laws may apply mainly to artificial situations does not, however, mean that it is not an important part of visual ordering, and indeed in decorative and abstract art it in fact makes it particularly relevant. As a result, we will examine gestalt in further depth here.

Gestalt theorists delineated a number of laws, including the law of closure, the law of good continuity, the law of proximity, and the law of similarity. These are illustrated by Figure 106 (p. 281). From the left of the figure we can see the law of closure, which states that the visual system 'closes' a break in a line, the law of good continuity, which states that we perceive joined lines that run in the same direction as sections of the same line, the law of proximity, which states that the visual system perceptually groups objects that are close to each other, and the law of similarity, which states that the visual system perceptually groups objects that are similar to each other. Two other laws are the law of common fate, which states that objects that move in a similar way are perceived as a unit, and the law of past experience, which states that objects that have been perceived around the same time will tend to be perceived as a group. In this thesis we are dealing primarily with still art, so we will not deal with these final two here.

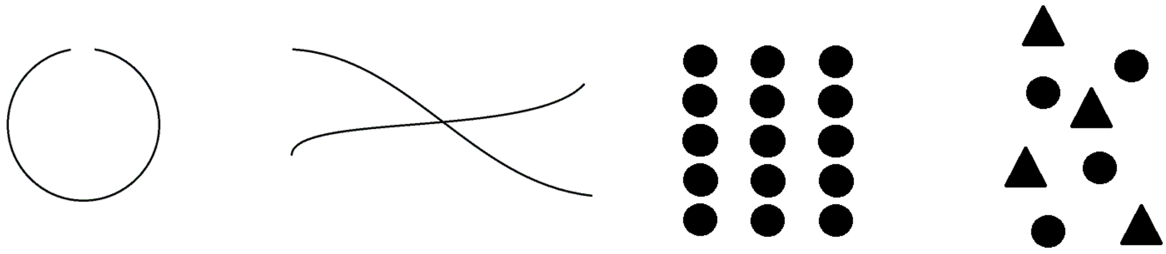

Figure 106 Gestalt Laws. Closure, Good Continuity, Proximity, Similarity. Diagram by the author.

The above laws can be divided into two types: those of completing objects (law of closure and law of good continuity), and those of arranging objects (law of proximity and law of similarity). The law of proximity and the law of similarity describe a gestalt property known as *perceptual segregation*. Perceptual segregation describes the way a viewer presented with a number of objects will mentally group those objects depending on properties such as proximity, similarity in shape, similarity of size, and similarity in colour.

Recent research has discovered additional laws. These include the theories of *uniform connectedness* and *contour segregation*. These theories involve the overall connectivity between objects, and can thus be classified as laws of completion. As implied by its name, the theory of uniform connectedness states that the visual system perceives any connected area with uniform visual features as a single unit (Palmer & Rock, 1994). Figure 107 (p. 282) gives an example of this relating to colour: in the figure, the green squares seem to form themselves into two areas, and the red squares also seem to form themselves into two areas.

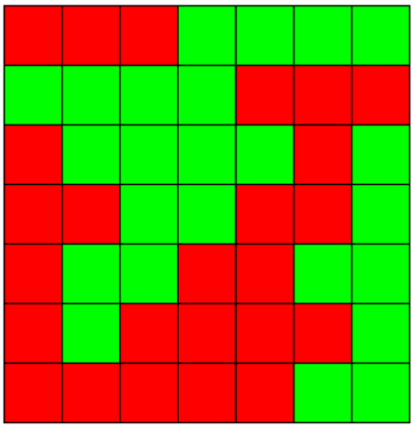

Figure 107 Uniform connectedness: the green squares seem to form themselves into two areas, and the red squares also seem to form themselves into two areas. Diagram by the author.

There is some disagreement, however, about whether uniform connectedness takes precedence in perception over the laws defined by the early gestaltists. There is some evidence that uniform connectedness is of most importance when multiple objects are considered (Eysenck & Keane, 2010, pp. 82–83).

Somewhat in competition with the theory of uniform connectedness is the theory of contour segregation. The theory of contour segregation argues that the visual system identifies areas of strong lines to distinguish between objects, rather that identifying areas of similarities. The theory is the result of experiments on the way that the visual system combines binocular vision and the images involved in motion perception. Such studies imply that the visual system arranges 'pieces' from different eyes and different images over time (Blake & Sekuler, 2006, p. 158). Figure 108 (p. 283) has strong black outlines added to the grid of Figure 107 (p. 282). These seem to 'overpower' the red and green area defined by contour segregation.

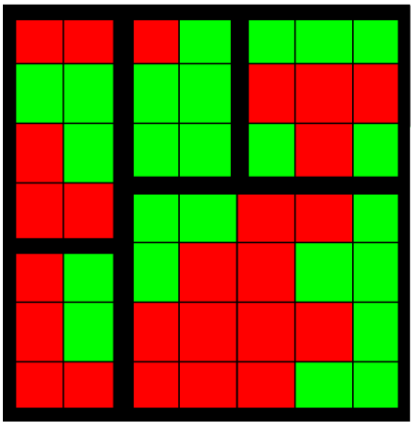

Figure 108 Diagram showing the conflict between uniform connectedness and contour segregation. Diagram by the author.

The conflict between uniform connectedness and contour segregation is an example where a stimulus has a number of different ordering properties that may be present in the same image, but that may contradict each other. Conflicts between the properties identified by earlier gestalt psychologists, such as those illustrated in Figure 109 (p. 283), have been studied systematically by later researchers, and have become known as *gestalt conflict*.

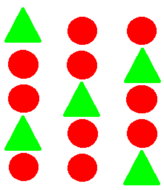

Figure 109 Gestalt Conflict: grouped by proximity (vertical) or similarity (green triangles and red circles)? Diagram by the author.

We saw earlier in the Duccio how the visual system deals with the problem of conflicting information in object recognition, so the examination of conflict between different gestalt properties will allow us to investigate the visual system's overall approach to visual conflict.

GESTALT CONFLICT

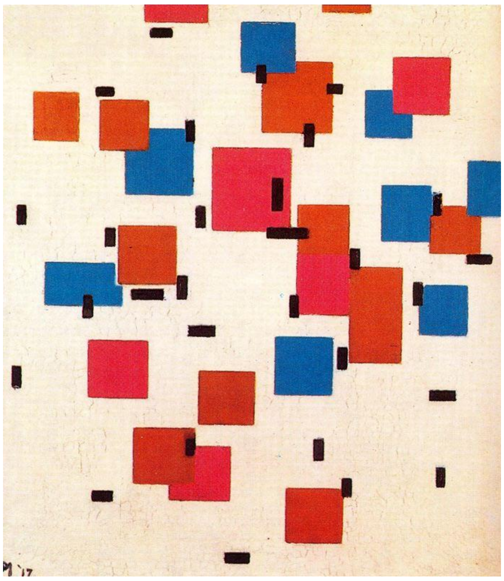

Figure 110 Piet Mondrian. *Composition in Colour A, also known as Composition in Blue A.* 1917. Oil on canvas, 50 x 44 cm, Otterlo: Rijksmuseum Kröller-Müller.

Consider for a moment Figure 110 (p. 284). As we look at it, our visual system orders it in terms of proximity, so there seems to be 'clumps' of shapes. However, our visual system also orders it in terms of size and colour. For example, the small black rectangles are seen as one group and the large coloured rectangles are seen as another. This raises the issue of gestalt conflict, namely which law 'wins', in this case the law of proximity or the law of similarity. In order to investigate this we will look further at the work of Mondrian, as well as experiments into gestalt conflict.

In the 1910s, Mondrian moved towards full abstraction and furthered his exploration of colour. In 1917 Mondrian notably started to give his paintings names in the form *Composition in X*, where X was line, colour, etc. Colour, then, is the primary feature of the above painting, as well as its sister painting, the similar *Composition in Colour B*, painted in the same year. Mondrian wrote in a letter to Theo van Doesburg:

> As to the blue, you are also right. Although the light in the Stedelijk does seem to change the colour values. In my (too small) studio, the effect was different. This is only a technical question: I believe that my work should be made in the place it is to hang, and in direct relation to that environment.

Mondrian, 1917, quoted and translated in (Bois, Joosten, Rudenstine, & Janssen, 1994)

Mondrian, though only working with three colours, was aware of the importance of the balance and effect of those colours. Given that the painting's composition involves other features, such as shape, occlusion, and the effect of the illusion of movement of the black rectangles, why did Mondrian suggest that this painting is primarily about colour? And given that there are three colours in the painting, why did he think that the painting was primarily about the colour blue? We will see that experimental psychology will provide an answer.

Experimental research has investigated this type of situation. Quinlan and Wilton performed experiments whereby volunteers were presented with sets of objects whose features, such as proximity, shape and colour, do not readily form clear clusters. Based on their findings they outlined the procedure by which the viewer unconsciously mentally orders objects:

1. The viewer initially forms mental clusters according to **proximity**.
2. If the clusters formed in Stage 1 do not have **within-cluster similarity** (i.e. in every cluster most of the objects have the same shape, size and colour, etc.), the viewer looks for other ways of grouping.

3. If there are similarities between objects from different clusters, known as **between-cluster similarity**, the viewer will re-cluster according to similarity or proximity.
4. If there are a number of within- or between- cluster differences, the viewer will often prioritise **colour**.

(Quinlan & Wilton, 1998)

In order to apply Quinlan and Wilton's ideas to Mondrian's painting, let us begin by identifying the different types of objects in the painting. There are:

A. Small vertical black rectangles of varying lengths
B. Small horizontal black rectangles of varying lengths
C. Large blue rectangles of varying sizes and dimensions
D. Large pink rectangles of varying sizes and dimensions
E. Large orange rectangles of varying sizes and dimensions

We can now apply the rules Quinlan and Wilton deduced from their experiments to the Mondrian:

1. The shapes are fairly evenly distributed around the canvas, but there is still some proximity. There might be some disagreement about the identification of proximity, but the following diagram presents the main clusters:

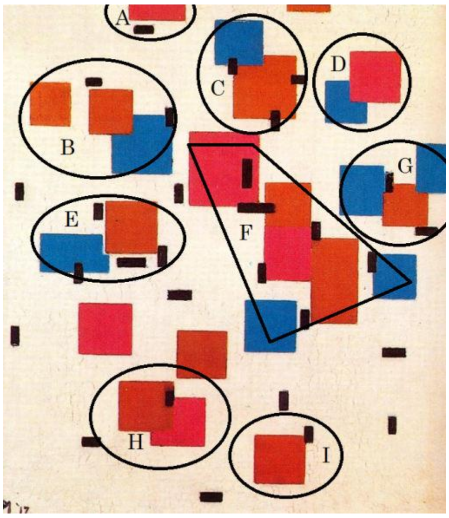

Figure 111 **Piet Mondrian.** ***Composition in Colour A, also known as Composition in Blue A*****. With proximity clusters drawn. Additions by the author.**

2. We must now ask whether each of the clusters have within-cluster similarities. In order to do this, we can create a table of the types of objects within the clusters, and use this table to create a graph:

Table 7 Variations in cluster frequencies

Cluster	Small black rectangles		Large coloured rectangles		
	Vertical	Horizontal	Blue	Pink	Orange
A	0	1	0	1	0
B	1	1	1	0	2
C	2	1	1	0	1
D	0	0	1	1	0
E	3	1	1	0	1
F	6	1	1	2	2
G	1	1	2	0	1
H	1	0	0	1	1
I	1	0	0	0	1
Hypothetical even cluster 1	1	1	1	1	1
Hypothetical even cluster 2	3	3	3	3	3

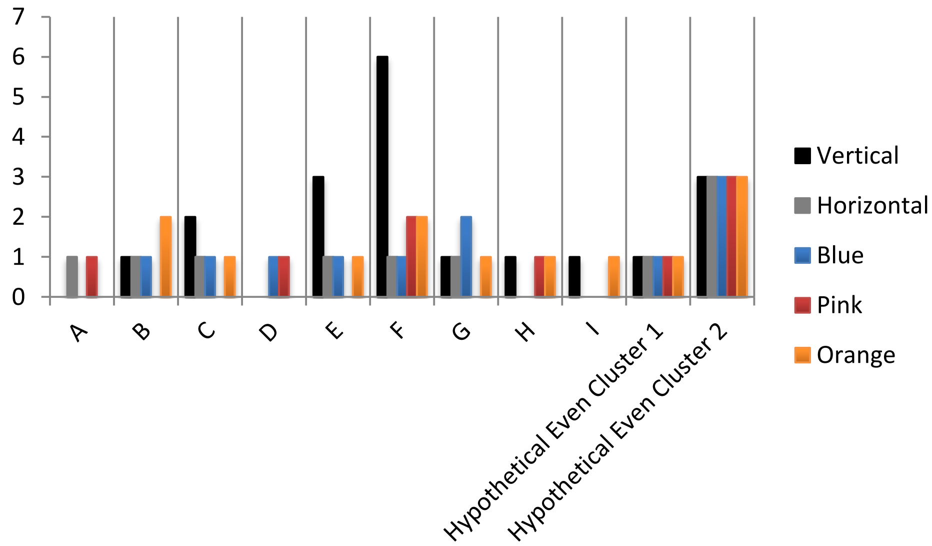

Figure 112 Variations in cluster frequencies. Diagram by the author.

If there were no within-cluster similarities, we would find that the graph of each of A, B, C, … would look similar to those for *Hypothetical Even Cluster 1* and *Hypothetical Even Cluster 2*, i.e. with each value equal. This is what we find largely, although there are a few spikes, most notably in cluster F. We can thus say that there are few within-cluster similarities, and thus the viewer looks for other ways of grouping.

3. The two main between-cluster groups are one group of small and black rectangles, and one group of large and coloured rectangles. There are internal differences between these groups: the black rectangles have different lengths and directions, and the coloured rectangles have different sizes, dimensions, and colours. We can thus argue that while between-cluster similarities are stronger than within-cluster similarities, there are still between-cluster differences.
4. Due to this, the viewer will perceive groups of coloured objects. Notably, the blue rectangles group together, and form a ring shape.

We should note, however, that there are other perceptual processes involved in viewing this picture. One of these processes causes a motion effect of the small black rectangles, which each seem to be moving in the direction of their two longest sides. There are also two three-dimensional effects. One is formed by colour, which can be seen in the way the orange rectangle in cluster I floats out in front of the lowest blue rectangle in cluster F. Another three-dimensional effect is occlusion, which can be seen in cluster B, where the orange rectangle appears to be in front of the blue rectangle. We can note that these three-dimensional effects interact in a particularly dynamic and contradictory way. For example the blue rectangle in cluster C occludes the orange, thus forcing a perceptual reversal of the effect of the orange and blue rectangles in clusters I and F; the blue rectangle appears in front of the orange due to the occlusion, whereas, as we saw in the subsection 'Colour Vision—Opponent Process Theory's Brightness Channel' of *Chapter 1* (p. 132), the colours would cause the orange to appear in front of the blue.

Generally, though, Quinlan and Wilton's experiments demonstrate that proximity plays a major role in perceptual grouping, and we can find this in *Composition in Colour A*. We have seen that Mondrian intuitively took a number of steps to suppress proximity grouping by arranging the rectangles fairly evenly over the canvas. Where there is proximity, Mondrian ensured the resulting clusters had little within-cluster similarity. The between-cluster similarities are strong, but have enough differences for the viewer's perception still to be unresolved. As a result, there is a final grouping by the visual system: that of colours, notably blue.

We are now in a position to answer the question of why blue is a primary feature of this painting. The experience of viewing this painting involves the following. The viewer is presented with a set of objects that stimulate the visual system with the desire to order. The visual system's attempt to perform this ordering is frustrated at each step, until the only way left to find order is colour. Thus, the mind is provoked to perceive primarily in terms of colour, and the most obvious pattern is found in the colour blue.

We have thus seen that not only do gestalt theories of perceptual ordering play an important role in the mental processing of artworks, but so do the visual system's attempts to resolve the conflicts between these processes. It is illuminating to note that though Mondrian would have had no knowledge of the theory gestalt conflict, he nevertheless had an unconscious understanding of such phenomena, and was thus able to use these mental processes in his paintings.

CONCLUSION

Firstly, we considered gestalt psychology in general. This approach has had a significant amount of research performed into it, and there is a significant amount of evidence to back up its claims. This includes studies into how the visual system deals with the phenomenon of there being a number of conflicting gestalts in any given visual stimulus.

Secondly, we considered what conflicts in gestalt tells us about visual processes, and how this explains artistic processes. We saw earlier in the Duccio that the theory of scales provides evidence that the visual system attempts to find a coherent interpretation of a visual stimulus even when the stimulus provides conflicting information. With the Mondrian, we saw that the visual system begins by ordering using proximity, and then looks for inconsistencies in these groups, causing it to search for new groupings. This leads to the conclusion that the visual system's attempt to seek a coherent interpretation, even in the case of conflicting information, is a feature of both the visual system's object-recognition subsystem and its organisation subsystem. This implies that finding a coherent interpretation of a stimulus is a key feature of the human visual system in general.

Thus, both the figurative and abstract elements of art rely on and exploit the phenomenon of the mental search for coherence in visual interpretation. This mental process of defining a single interpretation of a visual stimulus provided Duccio with a neat way of depicting an intricately patterned cloth without having to delineate the pattern over the cloth's folds. The process also, however, provided artists with deeper potential.

Painters such as Mondrian play on this process for artistic effect. When looking at *Composition in Colour A* our minds search ceaselessly for the underlying order, which our visual system assumes is there, but Mondrian prevents us from settling on the initial interpretation of proximity, instead leading the viewer towards an interpretation of order in colour.

Mondrian wrote:

> Every true artist has been inspired more by the beauty of lines and colour and the relationships between them than by the concrete subject of the picture.

Mondrian, quoted in (Junutytė, 2014, p. 117)

> It is possible that, through horizontal and vertical lines constructed with awareness, but not with calculation, led by high intuition, and brought to harmony and rhythm, these basic forms of beauty, supplemented if necessary by other direct lines or curves, can become a work of art, as strong as it is true.

Mondrian, 1914, quoted in (Elder A. , 2006, p. xviii)

Mondrian saw one of the goals of art being the exploration of abstract construction and the exploration of visual experience. In his case these processes were explored without the theoretical apparatus of psychology, but as we have seen above experimental science adds a new dimension of understanding to the creation of art.

Another example can be seen in the work of Salvador Dalí (1904 –1989), notably his 1940 *Slave Market with the Disappearing Bust of Voltaire.* This painting uses the search for coherent interpretation to a different effect. In the painting two figures of nuns standing side by side appear to turn into the face of Enlightenment writer Voltaire. Our visual system first detects

Voltaire, but then starts to detect that Voltaire's eyes are the heads of two nuns. The visual system then searches for other features of nuns, and finds them in the form of dresses and fabric. We then, however, see that the nuns' collars are undefined. Finally, we note that the collars look a bit like cheeks and a nose, and we find ourselves back at Voltaire, and the process starts again.

Unlike Duccio, Dalí passes our eye to different features of the face/nuns figure, disrupting rather than forming a single mental interpretation. Because of our visual system's desire to find a coherent interpretation, we seek endlessly for the solution, but are continuously passed around the various features of the face/nuns. Dalí is thus able to force us to think, as close as simultaneously as is possible, about pre-Enlightenment theology, as represented by the nuns, and post-Enlightenment reason, as represented by Voltaire.

This attempt at finding a coherent interpretation of an object could be explained in evolutionary terms. If an organism, say a cat, detects another organism, the cat would need to identify the other organism very quickly in order to decide how to react to it. If it was a mouse, the cat should pounce, but if it were a dog, the cat should flee. The need for the cat to quickly form an interpretation of an object explains why the visual system does not need replete information about the object.

The environment often provides conflicting information about subjects. For example, the apparent size of an object changes depending on its distance from us, but information such as blurriness and position on land allows us to compensate for variations in an object's apparent size, allowing us to judge the actual size of an object. Conditions such as fog, greater distance, and lack of prior experience of an object might make it difficult to judge the size of an object, and furthermore might provide conflicting information. If an object appears lower in the field of vision it appears closer, and if an object is blurry it appears further away, yet atmospheric effects might cause an object to appear blurred, and thus further away, even though the object is close to the bottom of the visual field.

The visual system will need to make a judgement on the information available. It will have to do this quickly, because precious food might escape, while dangerous predators might catch the organism if the organism delays. This causes the organism to accept that a stimulus might provide conflicting information, but to 'gamble on' a particular interpretation, while being aware that this interpretation might be erroneous. It is this ability to accept an interpretation of a subject matter, while accepting it might be wrong, that may provide an explanation of how our visual system can allow us to recognise the subject of a picture. A painting of a vase of flowers, for example, is not a vase of flowers, but the visual system forces an interpretation, while at the same time causing us to bear in mind that the interpretation is only provisional. This possibly provides a solution to the twofoldness problem outlined by Wollheim that we noted earlier (Wollheim, 1968).

PATTERN RECOGNITION, AND DECORATIVE ART (APPLICATION OF PSYCHOLOGY TO ART 9)

INTRODUCTION

There have been many studies that use an analogy between language and decorative patterns. Such analogies date back at least to Owen Jones's 1856

The Grammar of Ornament (Jones, 1856) (Jespersen, 1987), and have continued with such studies as David Castriota's 1981 *Continuity and Innovation in Celtic and Mediterranean Ornament. A Grammatical-Syntactic Analysis of the Processes of Reception and Transformation in the Decorative Arts of Antiquity* (Castriota, 1981). Westphal-Fitch et al., however, point to the lack of psychological studies that involve such analogies, despite the promise of such an approach (Westphal-Fitch, Huber, Gómez, & Fitch, 2012, p. 2008). They did, however, produce a study themselves and this study will be the basis of this section.

The section is divided into three subsections. 'The Geometry of Symmetry' (p. 295) examines the mathematics behind symmetry, and in particular how the application of group theory. We will see that there are three types of symmetry, mirror, rotation and translation, and that combinations of these can be understood using abstract algebra. 'The Psychology of Symmetry' (p. 299) examines how the brain processes objects in terms of order. 'Applications' (p. 302) examines how this can help us to understand art.

THE GEOMETRY OF SYMMETRY

Before examining Westphal-Fitch et al.'s study, it would be useful briefly to outline the theory of symmetry. Figure 113 (p. 296) shows the three types of symmetry: translational, rotational, and mirror.

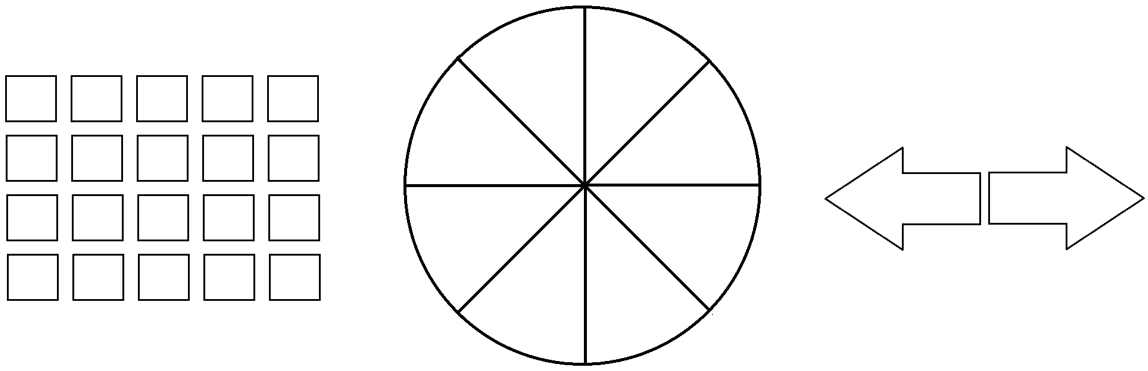

Figure 113 The three forms of symmetry: translational, rotational and mirror. Diagram by the author.

Not only can the three types of symmetry be used on their own, but they can be combined. Figure 114 (p. 296) shows a selection of possible combinations.

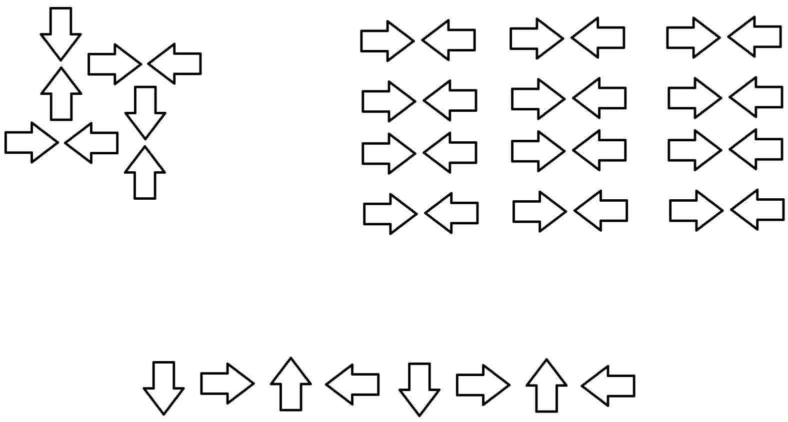

Figure 114 Combinations of symmetry types. Top left: rotational and mirror. Top right: mirror and translational. Bottom: Rotational and translational. Diagram by the author.

It is with the combinations of these elements of translation, rotation, and reflection that the language of ornament is formed. The study of combinations of the types of symmetry involves group theory. Hermann Weyl explains how this works with relation to operations on a pentagram (Weyl, 1952, p. 45). The group in question is the set of operations, together with combinations of these operations. The operations are reflection, and 72° rotations. In total we have the group:

Table 8 Star-shape Group

Objects:	72° anticlockwise rotation	reflection around a-f
	144° anticlockwise rotation	reflection around b-g
	216° anticlockwise rotation	reflection around c-h
	288° anticlockwise rotation	reflection around d-I
	360° anticlockwise rotation	reflection around e-j
Operation:	Combinations of the above	

We can readily see that this obeys the group requirements of closure, associativity, existence of inverses, and the existence of a neutral element, the conditions for a group. For example, multiple applications of the objects always leave us with a pentagram, 288° anticlockwise rotation is the inverse of a 72° anticlockwise rotation, and the 360° anticlockwise rotation is the neutral element.

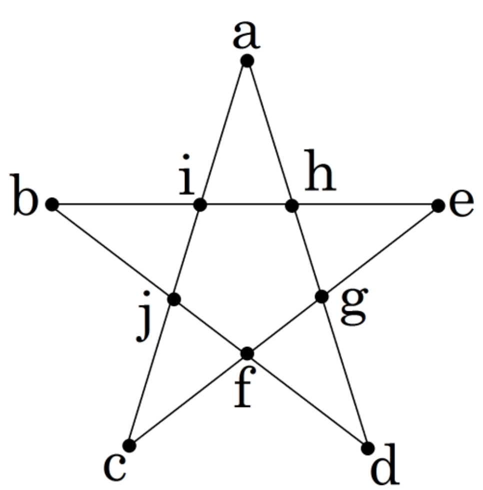

Figure 115 Pentagram. Diagram by the author.

Group theory has been used to demonstrate that there are 2 one-dimensional patterns, 7 ‘frieze’ or ‘band’ patterns, and 17 ‘wallpaper’ patterns, and to provide a basis on which to describe patterns.

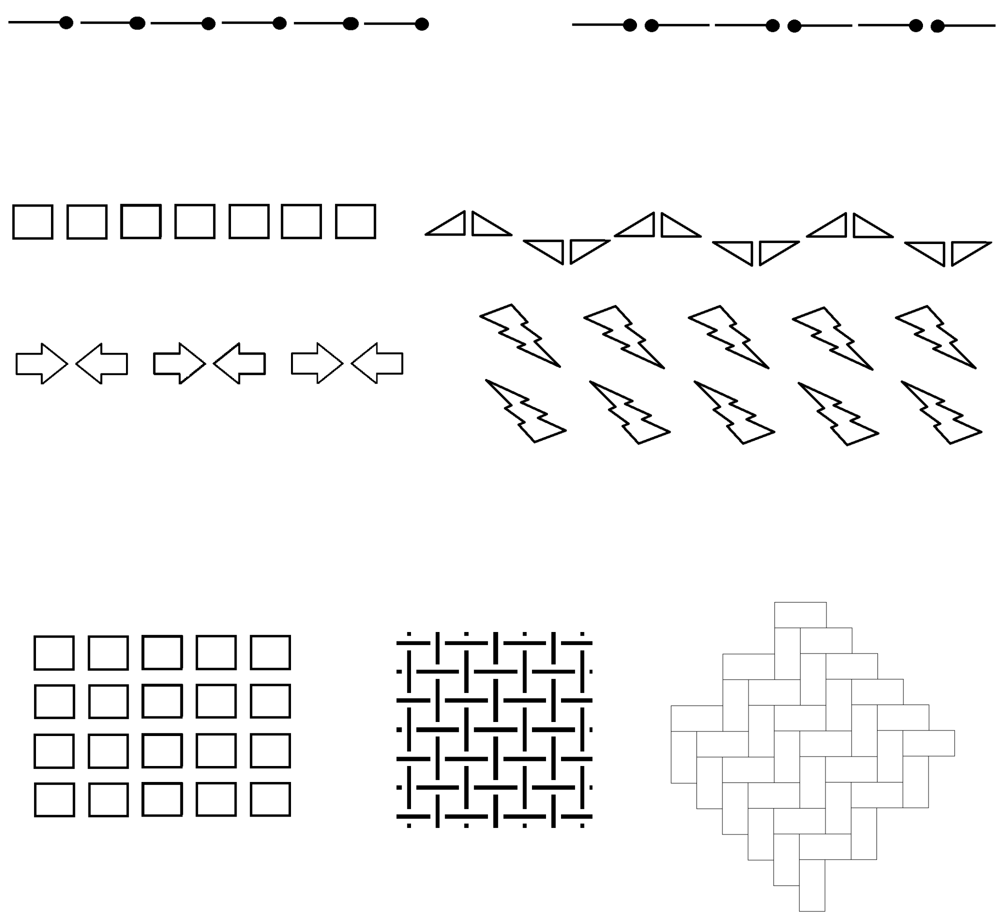

Figure 116 Types of pattern described by group theory. Top: 1-D patterns in 1-D space. Centre: ‘frieze’ or ‘band’ patterns. Bottom: ‘wallpaper’ patterns. Diagram by the author.

Combinations and permutations provide another useful tool for analysing patterns. The formulas of combinations and permutations give the exact number of possibilities for arranging a certain number of objects taken from a set of objects. For example, if we wished to make a band from 16 coloured tiles, we could calculate the number of possibilities as being equal to

$$^{12}P_{12} = \frac{12!}{(12-12)!} = \frac{12 \times 11 \times 10 \times \ldots \times 1}{1} = 479001600$$

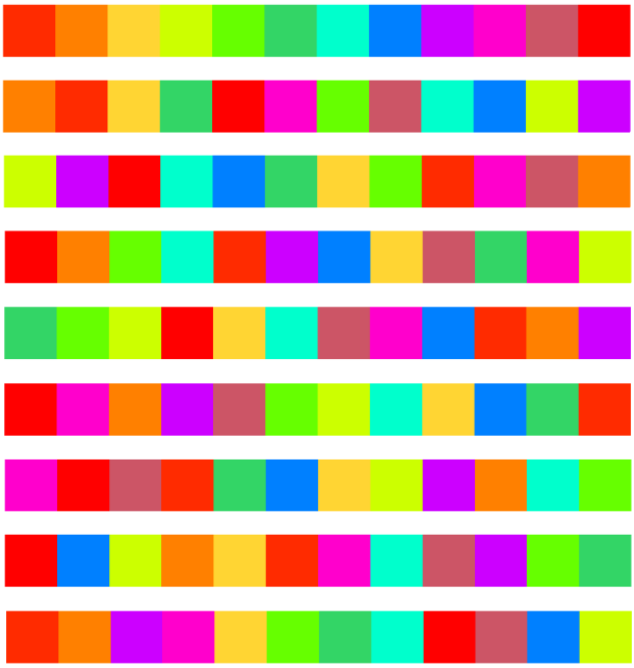

Figure 117 Diagram showing a selection from the 479001600 possibilities of arranging 12 tiles. Diagram by the author.

An example of this can be seen in the work of the American Minimalist artist Ellsworth Kelly, who would cut a sheet of paper into, say, sixteen squares, and re-arrange them. We might note that in this example Kelly could have produced

$$^{16}P_{16} = \frac{16}{(16-16)!} = \frac{16 \times 15 \times 14 \times \ldots \times 1}{1} = 20922789888000$$

different pictures.

THE PSYCHOLOGY OF SYMMETRY

We will now return to the work of Westphal-Fitch et al. For their experiments they produced a range of different two-dimensional patterns, such as chequerboard patterns, diamond repeat patterns, and zigzag patterns, as well as more complex patterns that resemble ceramic tiles. They tested these patterns on a range of subjects, including adults, children, humans with autism spectrum disorders, humans without such disorders, and pigeons. The tests included the subjects creating patterns they themselves liked, the subjects deciding which patterns created by the testers they liked, and performing tasks whereby the subjects detected flaws in regular patterns.

The tests Westphal-Fitch et al. performed were of three types: spontaneous pattern production, 'spot the flaw' tests, and a special type of 'spot the flaw' test which involved hierarchically-grouped-rotation verses serial-rotation tests. The sort of 'spot the flaw' tests used by Westphal-Fitch *et al.* can be seen in Figure 118 (p. 300). Some of the tests involved colour.

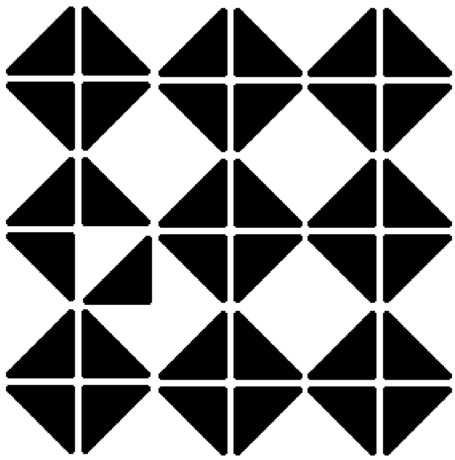

Figure 118 'Spot the flaw' type test, of the type used by (Westphal-Fitch, Huber, Gómez, & Fitch, 2012). Diagram by the author.

The graph in Figure 119 (p. 302) shows some of the most interesting results. The flaws in the stimulus used for sessions A and B, which are clearly serial, were detected quickly by the participants. Where the pattern is presented with less repetitions, as in that used for session D, the flaw is detected less quickly. Colour made detecting the flaw slightly easier for the pattern used in session A, while detecting the flaw in the pattern for session C took a considerable time. (The answer being that it is the square in the bottom-right-hand corner, which is the wrong way round.) The stimulus for session E took the participants the most time (Westphal-Fitch, Huber, Gómez, & Fitch, 2012, p. 2014).

The difference between sessions A and B show that colour is stronger than shape in indicating inconsistency, but only slightly. The difference between sessions B and D shows that a better delineation of a translational pattern makes inconsistency more obvious, and the difference is strong. The stimulus for sessions C and E involve rotational symmetry. The stimulus for session C also involves translational symmetry, and it is as if the inconsistencies in the translational symmetry deflect attention away from the inconsistencies in rotational symmetry. Though this gives some indication that translational symmetry is stronger than rotational symmetry, that there is only one rotational symmetry flaw to many translational symmetry flaws makes it difficult to confirm this conclusion. This idea that translational symmetry is stronger than rotational symmetry can be better seen in the very long reaction times from the participants for session E, in which the inconsistency in the serial rotational symmetry takes a long time to be detected.

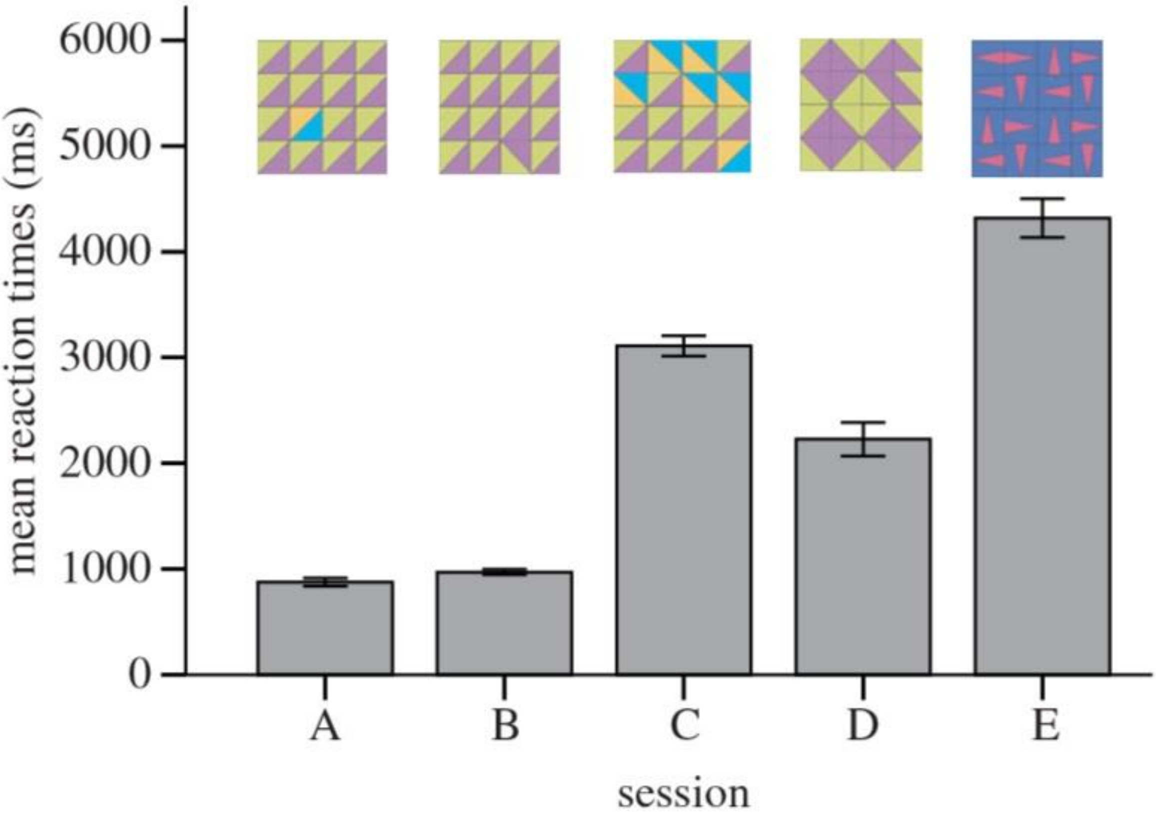

Figure 119 Graph of results from tests on speed of pattern recognition (Westphal-Fitch, Huber, Gómez, & Fitch, 2012, p. 2014).

APPLICATIONS

One of the most important designs in Celtic art is the Waldalgesheim running-tendril design (Figure 120, p. 304). Though the design at the top of the diagram appears complex, in fact it can be reduced to one of the seven 'frieze' designs we saw earlier, namely the P11G, or 'step', design. Group theory tells us that this design is a combination of reflectional and translational symmetries.

We noted above that flaws in rotational symmetry took participants in the tests longer to see than flaws in translational symmetry. As a consequence, if an artist wished to increase cognitive activity in their subjects, they might want to involve rotational symmetry.

The running-tendril of Figure 120 (p. 304) was a common motif in Celtic art, but as we have seen it involves mainly translational symmetry. We have seen in Westphal-Fitch et al.'s study that translational symmetry is easily detected by the brain, while rotational symmetry is harder to detect. We can see in the top image of Figure 120 (p. 304), which is the actual Celtic design, that the artist is attempting to make it increasingly difficult to see the underlying topology. An artist who wished to increase cognitive activity in their patrons would thus do well to add rotational symmetry to the translational symmetry of the design. In the detail of a bronze mount, found in the river Thames (Figure 121, p. 304) we see this is exactly what occurred. The translational symmetry of the running tendril is buried in a design based on rotational symmetry.

We might draw a further inference from Westphal-Fitch et al.'s study. The main clue as to the flaw in the stimulus from session E is mirror symmetry, but the rotational symmetry seems to deflect attention from this. We see the same process in the bronze mount from the Thames, where the 'glide mirror' symmetry is hard to find under the rotational symmetry, but would have been a feature of the tendrils known to Celtic patrons at the time, due to the ubiquitous nature of the design.

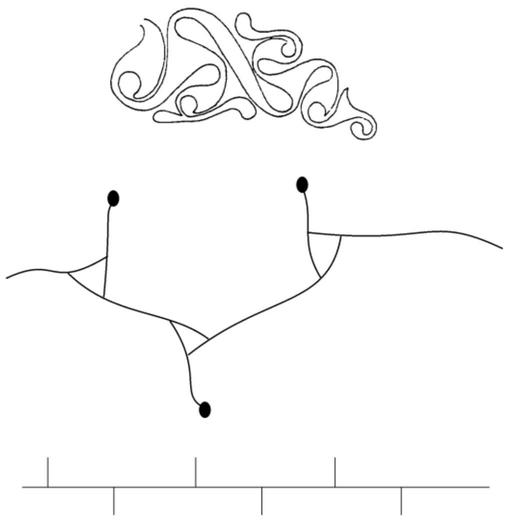

Figure 120 Top: Bronze mount from Comacchio (adapted from (Castriota, 1981, p. 887)). Middle: Schematic diagram of Waldalgesheim style running-tendril design. Bottom: Topological diagram of the running-tendril. Note how it is the P11G, or 'step', frieze pattern. Diagram by the author.

Figure 121 Pattern found on an Iron Age cast bronze finial, possibly found in the Thames at Brentford. Diagram by the author.

CONCLUSION

We can thus conclude that the visual system does not only identify objects, but attempts to find ways of grouping them. We can also see that the visual system's grouping procedures favour certain types of patterns, such as translational symmetry, over others, such as rotational symmetry. This explains why certain types of pattern, such as rotational patterns, may be favoured by artists, and may indicate that the artists are looking for a complex effect.

We saw in the section 'Conflicts in Interpretation: Gestalt Conflict (Application of Psychology to Art 8)' (p. 277) how such studies can explain the visual system's overall processes of selection, and thus illuminate how the visual system selects and identifies features for recognition. We will now return to the problem of identification, and see how this may illuminate our understanding of the ordering of features in depiction.

SEMANTICS AND SYNTAX, AND FIGURATIVE ART (APPLICATION OF PSYCHOLOGY TO ART 10)

INTRODUCTION

Normally, studies of the psychology of order involve the more abstract properties of art from studies such as that of gestalt. In this section we will see how psychological studies of the arrangements of figurative elements of images can also help us to understand perceptual ordering. We will see how analogies with linguistic structures and terms, such as semantics and syntax, can help us to better understand how the brain orders elements it recognises as objects from the outside world.

The section is divided into two subsections. 'Semantics and Syntax' (p. 306) examines the psychological research that has been carried out in this area. 'Semantics and Syntax in the Book of Kells' (p. 310) examines how the data gained from the experiments discussed in the first subsection can be applied to understanding the artistic processes of an example of an artwork.

SEMANTICS AND SYNTAX

In their paper 'Differential Electrophysiological Signatures of Semantic and Syntactic Scene Processing' Melissa L. H. Võ and Jeremy M. Wolfe examine the ordering of images. They classify the features of pictures in terms of two types, which they term semantics and syntax, and study the effect of oddities in pictures of these two types on the brain (Võ & Wolfe, 2013). Võ and Wolfe draw an analogy between language and pictures in an interesting way. They use the linguistic term 'semantics' to refer to what an object is, be it a computer screen, a keyboard, a soap dish, etc., and 'syntax' to refer to the arrangement of objects, the computer monitor placed behind the keyboard, a computer mouse to the left of the keyboard, etc.

Võ and Wolfe's study concerns oddities in this semantics and syntax. They tested subjects by showing them pictures of a desktop computer with a soap dish where the mouse should be, and other unusual arrangements. One example of such odd arrangements Võ and Wolfe studied can be seen in the table below:

Table 9 Syntax and semantic combinations

	Semantics Normal	**Semantics Odd**
Syntax Normal	Picture of a **desktop computer** with the **mouse** to the right	Picture of a **desktop computer** with a **soap dish** where its **mouse** should be
Syntax Odd	Picture of a **desktop computer** with the **mouse** stuck to the screen	Picture of a **desktop computer** with a **soap dish** stuck to the screen

The effect of the pictures on the subjects was measured by attaching 64 electrodes to each of the subjects' scalps to produce an 'electroencephalogram', a picture that shows which parts of the brain are stimulated and by how much.

The results of the trials demonstrated some interesting results. Among these are that inconsistent semantics caused less brain activity than inconsistent syntax, implying that the ordering of objects is more important to the mind than the meaning of individual objects. Oddly, while mildly inconsistent syntax caused more brain activity than non-inconsistent syntax, highly inconsistent syntax caused *less* brain activity than mildly inconsistent syntax. It is interesting to examine these inconsistencies in more detail, Figure 122 (p. 308). The mildly inconsistent syntax almost always causes the majority of brain activity, implying that there is a particular level of inconsistency in the brain that is of interest, after which the interest drops off.

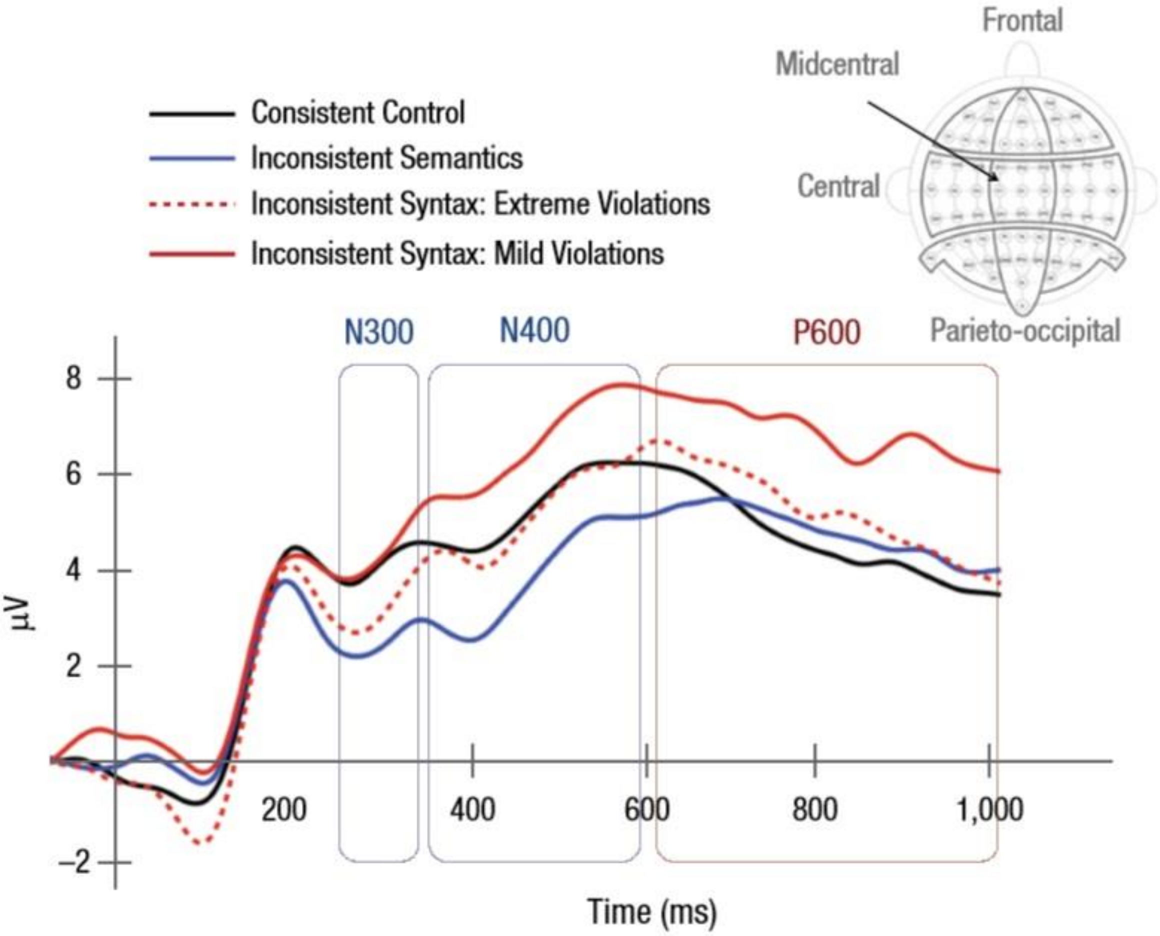

Figure 122 Graph showing brain activity as reaction time increases (Võ & Wolfe, 2013, p. 1821).

It is interesting to compare this second result with studies on complexity and interest, notably those of psychologist Daniel E. Berlyne (1924–1976) who we met in the *Introduction* (p. 18). To recap, Berlyne used experiments to discover what stimulus arouse an organism and motivates the organism's behaviour, and also examined the methodological problems that separate experimental science and art history (Konečni, 1978, p. 136). As we noted, his fundamental work is his 1960 *Conflict, Arousal, and Curiosity*, in which he examined the 'motivation of perceptual and intellectual activities'. He argued that organisms are aroused by sensory stimulation, that different stimulations cause an organism to have conflicting motivations, and that organisms actively seek out stimulation

(Berlyne, 1960, pp. 1–5). He argued that organisms have a desire to seek out novel stimulations, and the arousal that uncertainty brings, but also have the desire for relief from uncertainty; hence that organisms have conflicting desires for arousal and relief. Berlyne based his arguments on a range of scientific sources, including experiments on animals, observations of children and adults, neurophysiology, and information theory (Berlyne, 1960, p. 18).

Berlyne developed his previous analyses into a quantifiable relationship between arousal and complexity (Berlyne, 1974). Notably for us here, he argued that there is an inverted-U-shaped relationship between arousal and increasing complexity. As complexity increases an organism becomes more interested in the stimulus, but after reaching a peak increasing complexity starts to make an organism less interested. We see something similar in Võ and Wolfe's results on syntax, whereby interest increases as syntax inconsistencies increase but then drop off.

Berlyne's work is said to have been of pivotal importance to modern psychological aesthetics (Matchotka, 1980, p. 113), though we should note that while the methodological areas of his work have indeed been influential, this specific theory has received conflicting support in subsequent experiments (Messinger, 1998, p. 558). That there is conflicting support for Berlyne's thesis implies that while there is truth in his findings, the effect of increasing complexity is likely to be dependent on the specific task.

We can make the following general conclusion. Brain activity increases in the following way:

1. inconsistent semantics
2. highly inconsistent syntax
3. generally consistent syntax and semantics
4. mildly inconsistent syntax

Over time, the first three swap over places, but the mildly inconsistent syntax remains the quality that maintains high brain activity.

SEMANTICS AND SYNTAX IN THE BOOK OF KELLS

In this subsection we will see how the interest in semantics and syntax can aid in the understanding of Northern European art. Northern European art, especially that of Celtic art, is one of absorption and transformation, something that has been described by writers such as David Castriota (Castriota, 1981). The way this mode of transmission works can be seen in ancient British coins (Figure 123, p. 311). The ancient British showed a distinct lack of interest in what Võ and Wolfe describe as semantics, concerning themselves primarily with the arrangements of the components of the objects and their ordering. We can see that they took Greek prototypes and transformed them according to their forms of art making. The first major writer on decorative art, Riegl, described a culture's form of art making as its 'will-to-form', or *kunstwollen*. Gombrich describes it perhaps more precisely for Northern European art as a 'will-to-make-conform' (Riegl, 1893) (Gombrich, 1979, pp. 65–66).

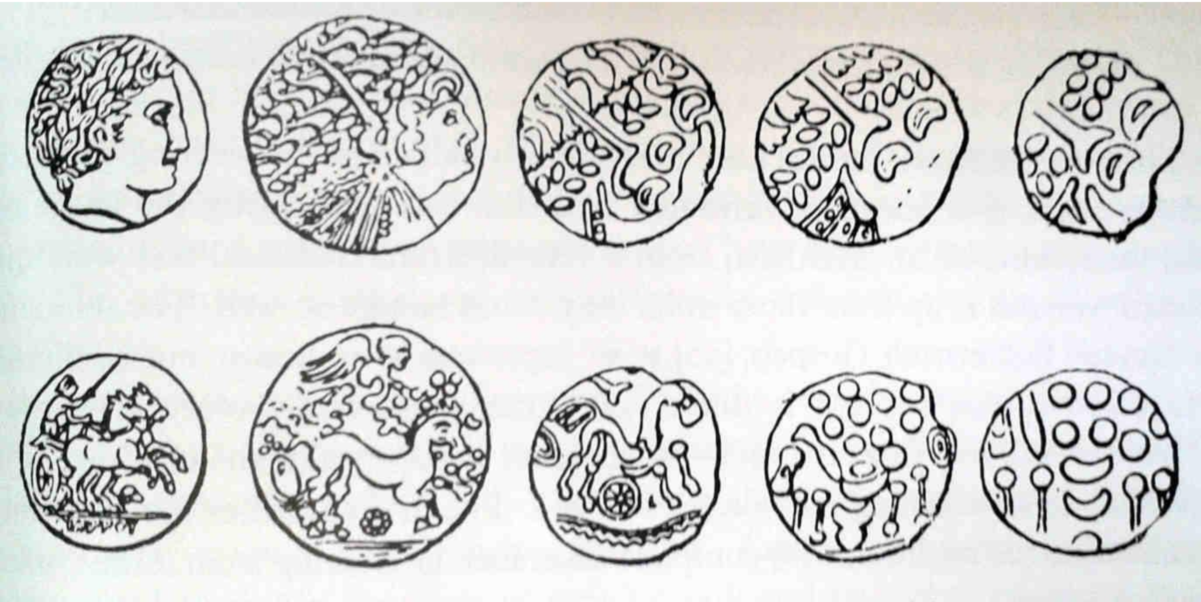

Figure 123 Ancient British coins and (left) Greek models, reproduced in (Gombrich, 1979, p. 65).

What was it that Northern Europeans wished to make art conform to? The above coins imply that ancient Northern European art was primarily decorative, but British Gospel manuscripts contain many figurative elements. What artistic processes underlie Northern European art?

It might be said that semantics was of less interest to ancient Northern Europeans than syntax. For example, consider Figure 124 (p. 312), of the Book of Kells. This scene has been interpreted either as 'Christ Praying at the Mount of Olives' or 'The Arrest of Christ'. Arguments about the truth of this are based around the interaction between the figures to either side with the figure of Christ, rather than the figures themselves, which provide little information (Harbison, 2011) (Meehan, 2012–2013).

Figure 124 The Book of Kells, 114r. Dublin, Library of Trinity College.

Whatever the interest the artists had in iconography, we can certainly note that they had a strong interest in abstract design. The complex spiral and interlace designs of the Book of Kells and other manuscripts belie an interest in complexity, and the interest in *mental activity*. As we saw, semantic inconsistency does not increase mental activity, nor indeed does extreme syntactic inconsistency. It is *mild syntactic inconsistency* that increases mental activity, and it is exactly this that can be seen throughout the Book of Kells. In Figure 124 (p. 312), for example, the figures and their component parts fit together well generally, but there is one inconsistency, namely that Christ's lower arms fail to conjoin with his body in an anatomically correct way. If we consider Figure 125 (p. 313) we see that the artist has followed the Byzantine prototype carefully (Meehan, 2012–2013). The arrangements of the hands of the Virgin around the Child, and the Child's holding the Virgin's hand and the Virgin's mantle are carefully reproduced. Yet the red in the Virgin's halo does not interact well with the angel's wings. The wings appear to sit in front of the red background, implying that the red is behind the halo, and not a part of its structure, something emphasised by the leaching of the red from the halo's lower left hand corner. This is inconsistent with the orange border of the halo clearly demarcating the red field, implying that it is a part of the halo's structure.

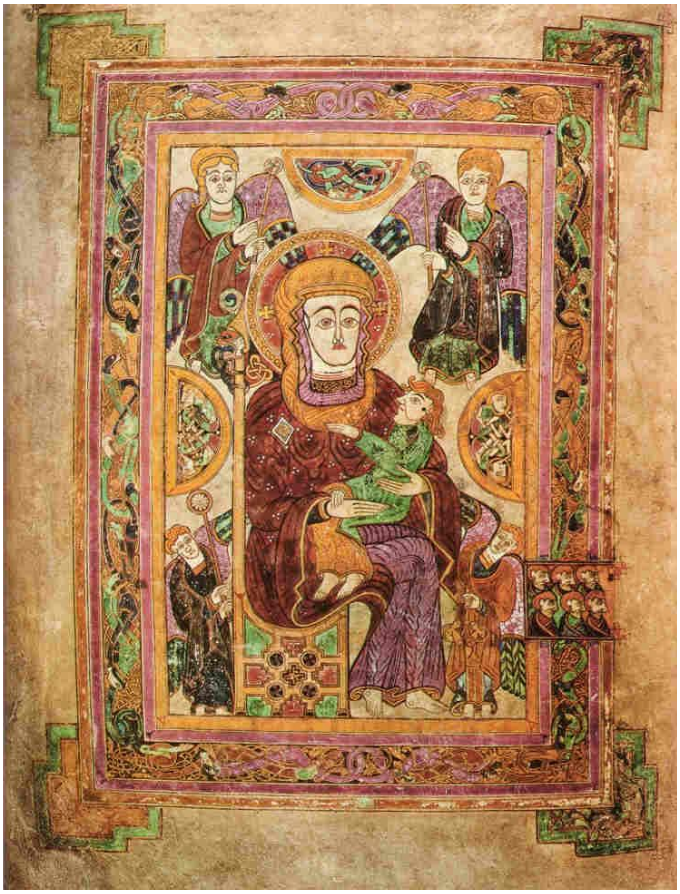

Figure 125 The Book of Kells, 7v. Dublin, Library of Trinity College.

Figure 126 (p. 314) shows a figure sitting on a chair holding a book. The book is carefully depicted as held by the figure, the figure's right leg is carefully depicted as bent to link the sitting figure to the chair, making the parts of the figure overall syntactically consistent. There is one mild inconsistency, however. It is not clear how the figure's left arm forms a part of the rest of the figure. We might observe two different interpretations of the figure's left arm. One is that the figure's left arm is it simply hanging to one side behind the gold panel on the right, as implied by the shoulder. The other is that it is covered with cloth and holding the bottom of the book. We might note that such mild inconsistencies occur throughout the Book of Kells.

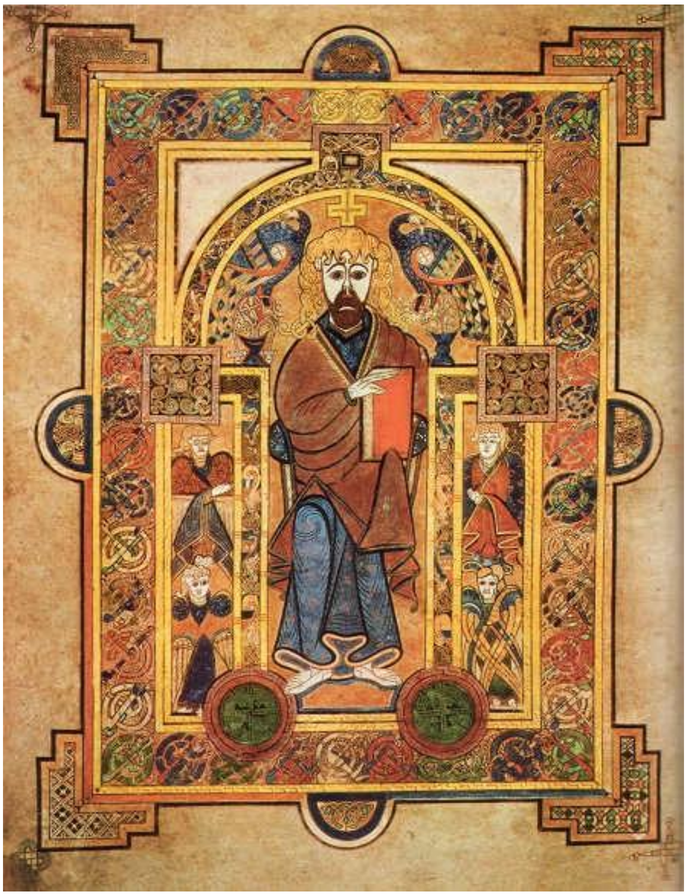

Figure 126 The Book of Kells, 32v. Dublin, Library of Trinity College.

CONCLUSION

The analysis of the 'semantics' and 'syntax' of the figurative elements of the Book of Kells leads us to the conclusion that the artists involved in its creation wanted to increase mental activity in the viewers of the manuscript. This use of mild syntactical inconsistencies can be seen as a complement to the mental puzzles presented in the intricate and complex interlace and spiral patterns of Insular art.

CONCLUSION

This chapter began with an examination of how the visual system mentally organises groups of objects. We have seen that despite the gestaltists being controversial in many respects, the laws they described such as the law of similarity and the law of proximity have indeed been verified by experiment. We have also seen that further laws can be added to them, including the law of uniform connectedness. It has been noted that gestalt laws tend to work best in more abstract and artificial situations, so laws such as uniform connectedness may increase the number of laws and help to explain areas of mental ordering that exist in the world of real objects.

We have also seen how the visual system deals with conflicts in interpretation, by forcing an interpretation. We have seen how this forcing of an interpretation does not stop the visual system from searching for other interpretations, and how this process of the provisional nature of visual stimuli processing provides a mechanism which explains how depiction can occur.

CONCLUSION

In this thesis I have used perceptual psychology to argue that the processes of creating pictures involve resemblance (examined in *Chapter 1*), the selection and possible distortion of features for depiction (examined in *Chapter 2* and *Chapter 3*), and organising principles (examined in *Chapter 4*). Thus depiction involves the artist selecting features of objects that provide information of interest, for example the vertices of cubes. It furthermore involves the artist applying to a surface marks that share, but may distort, visual properties of these features. The artist must also organise the arrangement of the objects depicted.

We have seen the way that the science of vision can both demonstrate why depiction is possible at all, and illuminate precisely the processes involved. We might recap on this here, beginning with a number of preliminary points.

Firstly, there is the issue of the reliability of the visual system. We have seen that the visual system is not 100% reliable, for example yellow light being indistinguishable from mixtures of pillarbox red and green, but that generally we can rely on our visual system. However, pictures, such as those on a television screen, might well exploit the ways the visual system can be fooled.

Secondly, we noted that the visual system attempts to interpret stimulus from the eyes. Light travels into the eye, and is converted into electrical signals that are then interpreted by the visual system. In Figure 95 to Figure 100 (p. 253), we saw that the visual system decomposes the stimulus into lines, using centre-surround cells. It then attempts to interpret these lines as indicators of space, namely as the converging lines seen in linear perspective, and the vertices of volumetric form. The visual system then recombines the information into a coherent model of the stimulus, and recognises it as a set of stone steps. We have seen how Biederman was able to demonstrate this process in his theory of geons, and specifically the notion of vertices.

Thirdly, we noted that the visual system attempts to interpret information even if contradictory information is present. I have argued that it is this basic process that (a) allows artists to create pictures at all, and (b) allows artists to omit and distort features in their pictures. Our visual system interprets two circles or dots above a line as a face, and thus humans 'see' faces seemingly everywhere, in clouds, in the moon, in brickwork, and in portraits by Rembrandt. More precisely, we might say that the visual system recognises two circles or dots above a line as a face, and thus sometimes misrecognises objects as faces. Other visual features of an object may cause an object to be recognised differently; for example the visual system might recognise the colour white and billowing texture as features of a cloud, and thus we still 'see' a face in a cloud. Notably for our discussion here, in the same way we 'see' a face in the brush strokes of Rembrandt.

We saw a number of examples of this process in artworks. We saw that the visual system recognises the vertices of the Penrose Triangle (Figure 20, p. 100) as properties of a three-dimensional shape, and thus we perceive the picture as being of a three-dimensional object despite such an object being impossible. In the conclusion of the section 'Conflicts in Interpretation: Gestalt Conflict (Application of Psychology to Art 8)' of *Chapter 4* (p. 291) we saw that the visual system constantly searches for a single coherent interpretation of Salvador Dalí's *Slave Market with the Disappearing Bust of*

Voltaire despite being frustrated by their being two possible interpretations. In the section 'Decomposition and Recomposition: Scales (Application of Psychology to Art 5)' (p. 210), we saw that the visual system actually forces an interpretation of Duccio's sleight of hand in the cloth of the *Rucellai Madonna*.

Fourthly, there is the property of the elasticity of recognition. This is closely related to the previous point. We noted that visual system recognises the vertices of objects and also combinations of vertices, which allow us to recognise many volumetric forms. We noted that there is a certain degree of elasticity in this process, which means that information that is slightly distorted can nevertheless be used by the visual system to recognise objects. We saw that as a result Giotto was able to depict volumetric forms, even though his linear perspective was incorrect.

Fifthly, there is the importance of the information and organisational concepts provided by a picture. We saw with the Bosch painting that the quantity and quality of information provided by a picture is a key feature; if important information is missing, such as vertices, the picture is less successful. Furthermore, the visual system searches for order in stimulus, and thus pictures are organised to communicate such organisational structures to the viewer.

We can thus note that understanding the processes of the visual system allows us to understand how depiction can be possible, and why it takes the forms it does. I have attempted to build a model of the how the processes of the visual system can actually explain the qualities of depiction.

We might thus say that depiction can occur because of the mental system of decomposition, interpretation, and recomposition. An artist exploits these properties: by drawing three lines meeting at a point, our visual system causes us to 'see' a vertex because it interprets these vertices as part of a three-dimensional structure. Our visual system tends to force an interpretation of a stimulus on us, perhaps because an organism has to react quickly to a stimulus to avoid death or to catch food. Thus when we see a picture, our visual system interprets it as the object depicted. The fact that our visual system can force an interpretation also leads to the possibility of artists such as Picasso distorting objects, due to the visual system forcing an interpretation even when the visual information provided to it is intrinsically illogical, and artists such as Leonardo leaving properties of objects out in pictures, such as colour.

We are still left with the problem alluded to in the third preliminary point above of why the visual system does not simply dismiss pictures once the viewer is aware that the stimulus is a picture. Our visual system may well accept contradictory information, and attempt to find an interpretation, but eventually (in fact almost immediately) we realise a picture is a picture. Why do we simply not see a painting by Raphael, and once we know it is a painting (which in most cases is straight away) does our visual system simply dismiss the stimulus as not being a woman or a Renaissance building? This is a problem that has engaged art historians and philosophers for a long time, perhaps most notably summed up by Richard Wollheim's notion of 'twofoldness', namely the idea that a painting is seem as an array of brushstrokes, and as of its subject simultaneously.

We might note here that Gombrich and Wollheim both had similar ideas about what Wollheim called 'twofoldness'. Gombrich called it 'illusion', and argued that humans cannot experience a paintings brush strokes and subject at the same time, but must alternate; with 'twofoldness' Wollheim argued that both are seen simultaneously. Studies into visual psychology might provide answers to this question, with studies of attention, such as the multiple spotlight studies we looked at earlier as well as other studies, being very promising (Matthen, 2005) (Newall, 2015).

Aside from providing explanations for the philosophical aspects of art, we should also note what we have learned about art history. For example, we learned from the multiple spotlights theory of attention that perception occurs in localised areas, which explains how inconsistent space can occur in pictures such as the Duccio and yet not necessarily be noticed by the viewer. Importantly, we learned from this that Renaissance perspective involved a change in the viewing of pictures; viewers and artists, such as Hogarth, became more critical of incorrectness in perspective. The theory of multiple spotlights suggests that viewers of art must have increased the number of changes in their attentional areas, so as to be able to spot inconsistencies, which are easy to miss in the 'unspotlighted' areas. Thus we were able to conclude that there have been changes in attentional behaviour in viewers since the Renaissance.

We saw that pictures generally do not 'send the same array of light through the pupil as does the subject matter itself'. Even in the case of a photo on a computer monitor, we saw that the monitor in fact sends only three wavelengths of light through the pupil. By understanding the properties of the visual system, we can see how a computer monitor or a printed sheet can use only three colours (as a result of there being three colour receptors in the eye), how line drawings can be perceived (due to the existence of centre-surround cells), and how pointillist paintings can be perceived both as their subject matter and as an array of dots (by the visual system's ability to perceive different scales of images).

An important additional point I examined is to understand the origin of visual processes. We saw that cultural as well as genetic processes are of importance, and examined how both cross-cultural psychology, and historical methods such as Baxandall's period eye method, can be used to elucidate the role of culture. Furthermore, we touched on the possibility of combined psychological/historical methods for examining this issue.

APPENDIX. MOTION DETECTION IN CINEMA (APPLICATION OF PSYCHOLOGY TO ART 11)

INTRODUCTION

In this appendix we will extend the topics dealt with in this thesis to moving pictures. We noted in the body of the thesis that still pictures involve mainly cone cells ('The Visual System', p. 49), but to examine moving pictures we will consider rod cells and motion detection. An interesting facet of this that we will examine it that rod cells, and consequently motion detection, work well in low light levels. This makes the use of low light levels particularly useful in a number of cinema genres.

The appendix is divided into two sections. 'Shaft' (p. 322) examines the role of the rod cells in terms of 1970 black liberation cinema. 'Aliens' (p. 323) examines the role of the rod cells in terms of horror cinema.

SHAFT

The first example that we will consider is a pivotal shot from the 1971 MGM action-detective film *Shaft* (director: Gordon Parks). The scene in question involves the black male protagonist, a private detective called John Shaft, having sexual intercourse with a white woman. Inter-racial sexual relations were not fully accepted by Americans at the time, so such an image would be both shocking and liberating to the audience. The filmmakers would therefore find it desirable to spring such an image on the audience unaware, to both shock the audience, and to create a sense of exhilaration in the liberation of such a then controversial action.

The filmmakers might want such a sequence to adopt the following pattern. Firstly, the sequence should gain the viewer's attention. Then, the viewer's anticipation should be aroused. This anticipation would be facilitated if the viewer could be kept unaware of what he or she would be about to witness. We can note that rod cells do not facilitate recognition, but can detect motion quickly; cones allow for recognition, but work slowly. As a result to achieve the above aim the filmmaker should show movement, preferably in the dark, then allow greater light, together with an object that would reveal the scene's shocking or liberating subject. This would all happen very briefly, and thus would be especially suitable for use in a film trailer.

The trailer to the film Shaft indeed uses a shot that makes full use of this process. At 0:38 minutes into the trailer we see a shot of a psychedelic Calder-like mobile partially obscuring two figures on a bed, then by 0:40 the naked figure of the black Shaft becomes clear. The room is dark, as is Shaft's black skin. Suddenly, the viewer sees a white object moving, and it becomes clear that the object is the hand of a white woman reaching from under Shaft. The viewer then deduces that the black Shaft is having sexual intercourse with a white woman.

In addition we might note that the use of this technique draws attention to both the black skin of the protagonist, and to the whiteness of his sexual partner. The director is thus able to shock and exhilarate the audience with the message of black liberation. The image makes a clear and very fast visual impression; the black-on-white sexual intercourse is heavily emphasised and made noticeable to the viewer.

ALIENS

The second example that we will consider concerns a sequence from the 1986 20th Century Fox horror-action-science fiction film *Aliens (Special*

Edition) (director: James Cameron). The first sight the viewer has of the dangerous adult aliens occurs at 56:02 minutes into the film.

Again, the image is dark, and motion is used to grab the viewer's attention. When the adult aliens are first shown, the viewer sees only vague shapes, which he or she is primarily aware of through movement. Unlike the figures in *Shaft*, however, the shapes remain amorphic until they actually attack the humans, and indeed they remain fairly amorphic in most shots in the film. The viewer is therefore aware that the aliens are dangerous, but cannot fully identify their shapes, which enhances their frightening nature. Movement and low light levels are, of course, the conditions under which our ancestors hunted for food at night. It is possible, then, that directors of horror films also utilise a primal memory of the fears of night hunting.

CONCLUSION

The rods in our eyes evolved to facilitate the detection of movement, especially in the dark. Filmmakers, however, have exploited this for another purpose, namely surprising or frightening viewers of their films. Some films involving dangerous creatures such as *Aliens* are often claimed to tap into 'primal' fears, without an actual elaboration of how these fears are aroused in the viewer. The above analysis of films such as *Aliens* goes some way to explaining the precise mechanism of this action, and help to extend the ideas developed in this thesis into the dimension of motion.

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